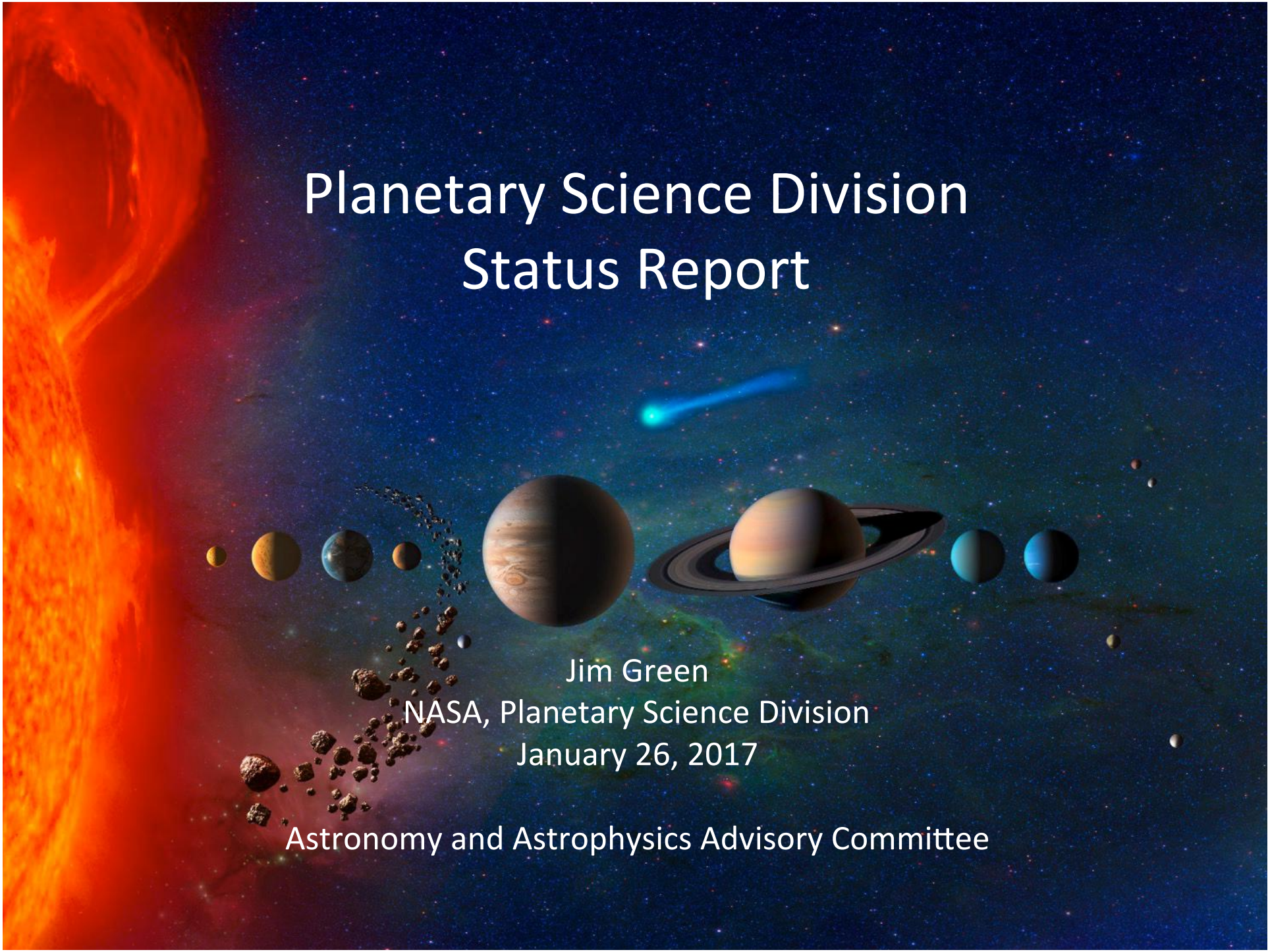
Planetary Science Division Status Report



Jim Green
NASA, Planetary Science Division
January 26, 2017

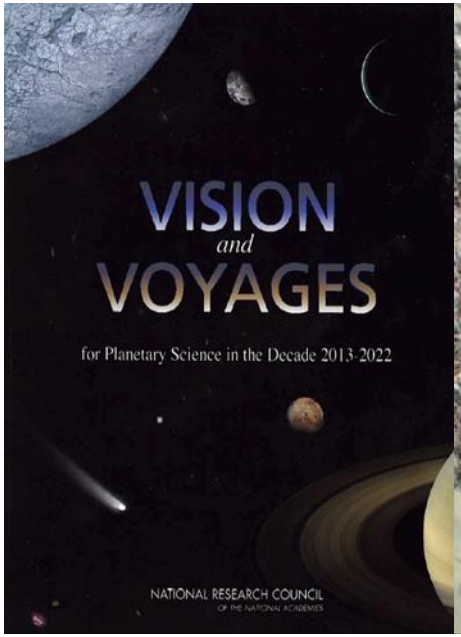
Astronomy and Astrophysics Advisory Committee

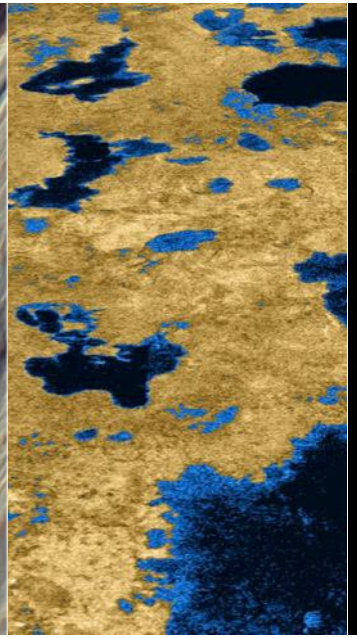
Outline

- Planetary Science Objectives
- Missions and Events Overview
- Flight Programs:
  - Discovery
  - New Frontiers
  - Mars Programs
  - Outer Planets
- Planetary Defense Activities
- R&A Overview
- Education and Outreach Activities
- PSD Budget Overview

Planetary Science

Ascertain the content, origin, and evolution of the Solar System and the potential for life elsewhere!





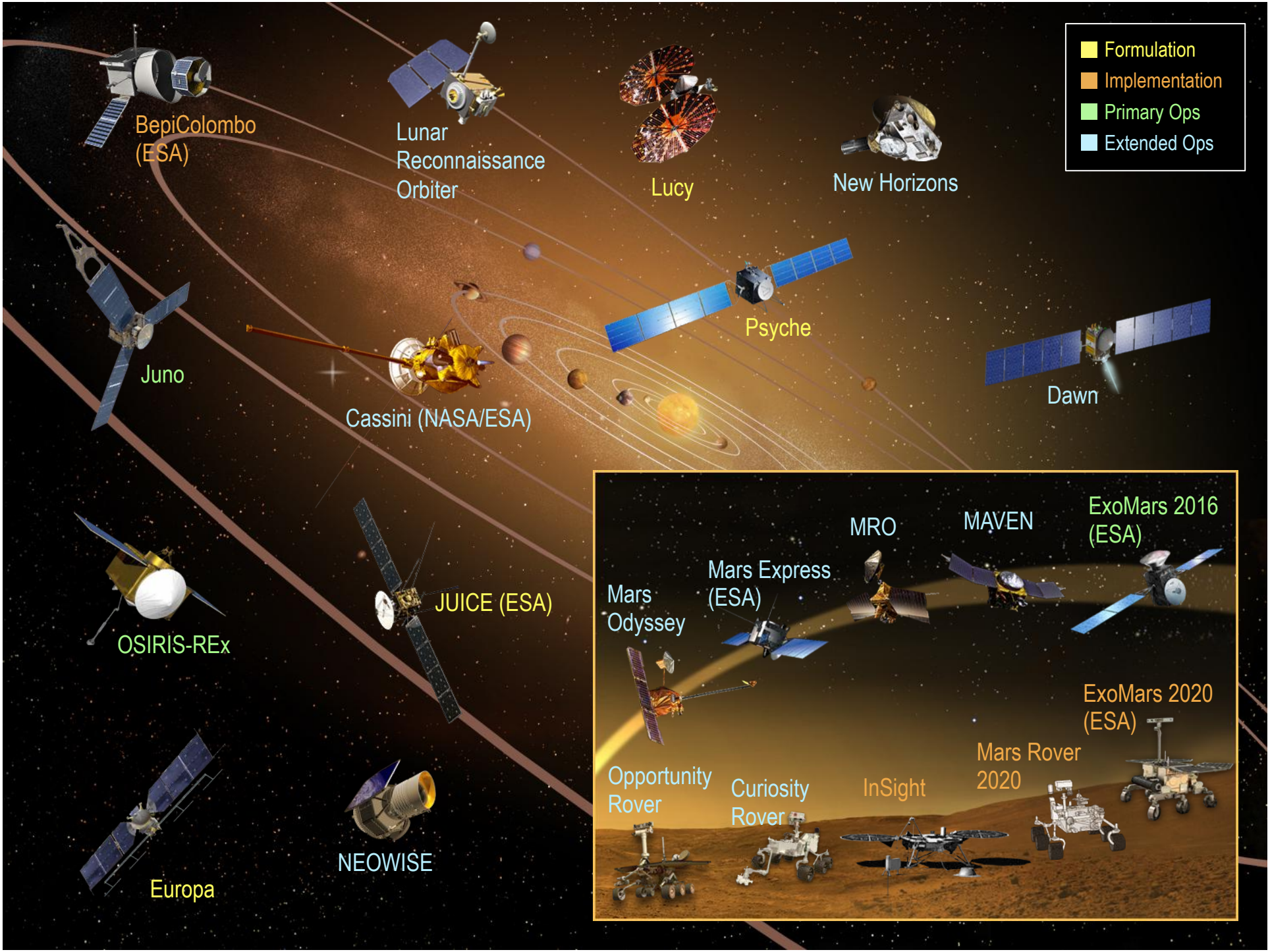
Objective 1.5.1
Demonstrate progress in advancing the understanding of how the chemical and physical processes in the Solar System operate, interact and evolve

Objective 1.5.2
Demonstrate progress in exploring and observing the objects in the Solar System to understand how they formed and evolve

Objective 1.5.3
Demonstrate progress in exploring and finding locations where life could have existed or could exist today

Objective 1.5.4
Demonstrate progress in improving understanding of the origin and evolution of life on Earth to guide the search for life elsewhere

Objective 1.5.5
Demonstrate progress in identifying and characterizing objects in the Solar System that pose threats to Earth or offer resources for human exploration


Formulation
Implementation
Primary Ops
Extended Ops
BepiColombo (ESA)
Lunar Reconnaissance Orbiter
Lucy
New Horizons
Juno
Cassini (NASA/ESA)
Psyche
Dawn
OSIRIS-REx
JUICE (ESA)
Europa
NEOWISE
MRO
MAVEN
ExoMars 2016 (ESA)
Mars Express (ESA)
Mars Odyssey
ExoMars 2020 (ESA)
Mars Rover 2020
Opportunity Rover
Curiosity Rover
InSight

Planetary Science Missions Events

2016

March – Launch of ESA's *ExoMars Trace Gas Orbiter*

*** Completed**

July 4 – *Juno* inserted in Jupiter orbit

September 8 – Launch of Asteroid mission *OSIRIS – REx* to asteroid Bennu

September 30 – Landing *Rosetta* on comet CG

October 19 – *ExoMars EDM* landing and *TGO* orbit insertion

December 11 – *Juno* second science perijove pass

2017

January 4 – Discovery Mission selection announced

February 2 - *Juno* third science perijove pass

February 9-20 - *OSIRIS-REx* begins Earth-Trojan search

April 22 – *Cassini* begins plane change maneuver for the "Grand Finale"

September 15 – *Cassini* enters Saturn and completes mission

September 22 – *OSIRIS-REx* Earth flyby

2018

May 5 - Launch *InSight* mission to Mars

August – *OSIRIS-REx* arrival at Bennu

October – Launch of ESA's *BepiColombo*

November 26 – *Insight* landing on Mars

2019

January 1 – *New Horizons* flyby of Kuiper Belt object 2014MU69

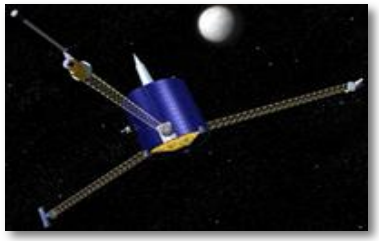
Discovery Program

Discovery Program

Completed

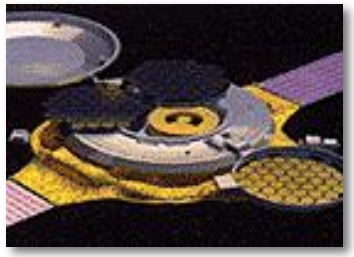
Mars evolution:
Mars Pathfinder (1996-1997)

Lunar formation:
Lunar Prospector (1998-1999)



NEO characteristics:
NEAR (1996-1999)

Solar wind sampling:
Genesis (2001-2004)

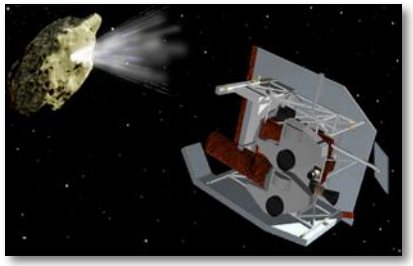


Completed

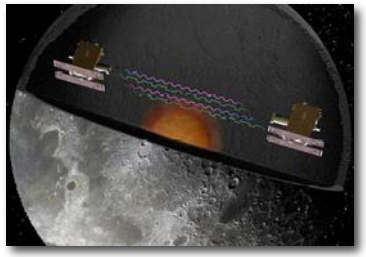
Comet diversity:
CONTOUR (2002)

Nature of dust/coma:
Stardust (1999-2011)

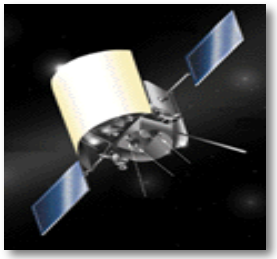
Comet internal structure:
Deep Impact (2005-2012)



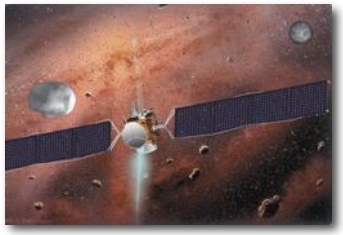
Lunar Internal Structure
GRAIL (2011-2012)



Mercury environment:
MESSENGER (2004-*2015*)



Main-belt asteroids:
Dawn (2007-*TBD*)

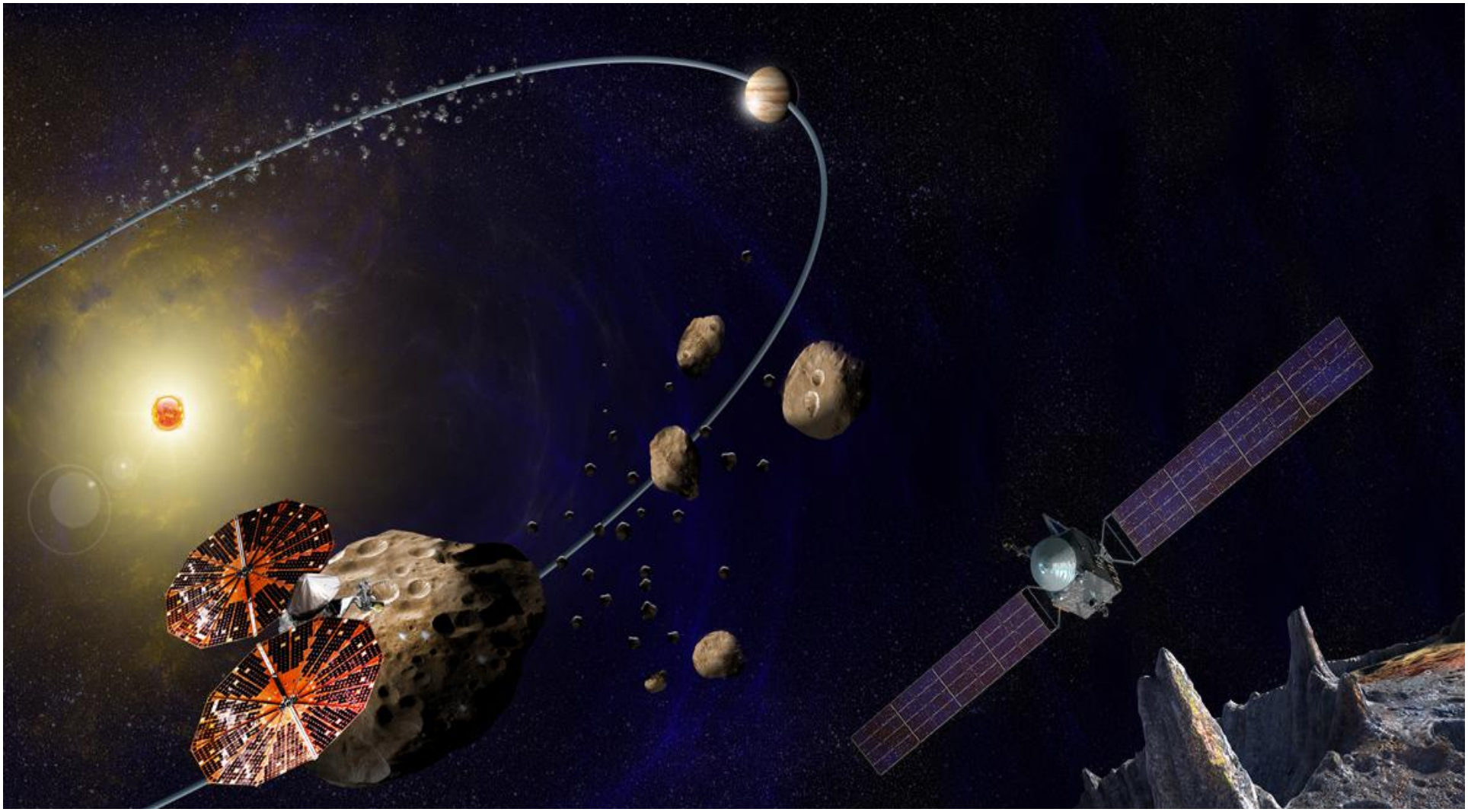


Lunar surface:
LRO (2009-*TBD*)

ESA/Mercury Surface:
Strofio (*2017-TBD*)

Mars Interior:
InSight (*2018*)

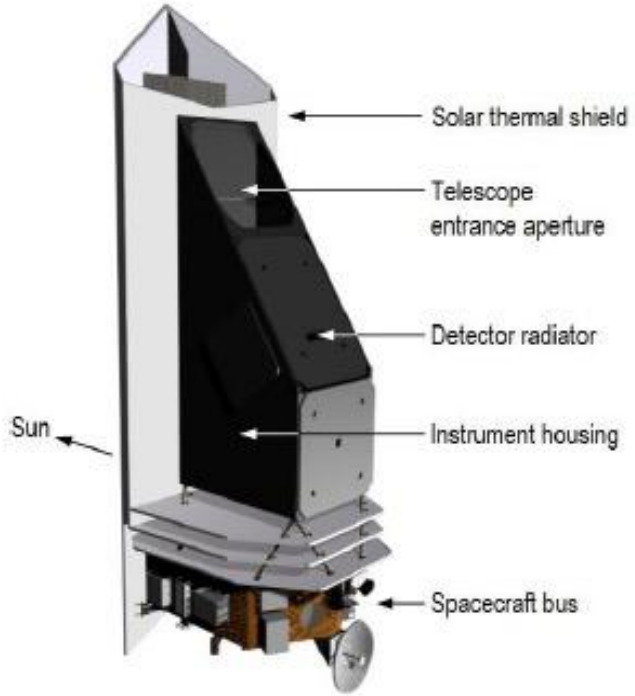
Discovery Selections 2017



Lucy: Surveying the Diversity
of Trojan Asteroids
PI: Harold Levison, SwRI

Psyche: Journey to a Metal World
PI: Linda Elkins-Tanton, ASU
Deep-Space Optical Comm (DSOC)

Discovery Selections 2017



NEOCam:
Near-Earth Object Camera
PI: Amy Mainzer, JPL

The Discovery Program selection of NEOCam for an extended Phase A effort is an acknowledgement that, even though it was not selected for full mission implementation, it is an important capability for the Agency that will continue formulation efforts to address issues identified in the Discovery evaluation process.

New Frontiers Program

New Frontiers Program

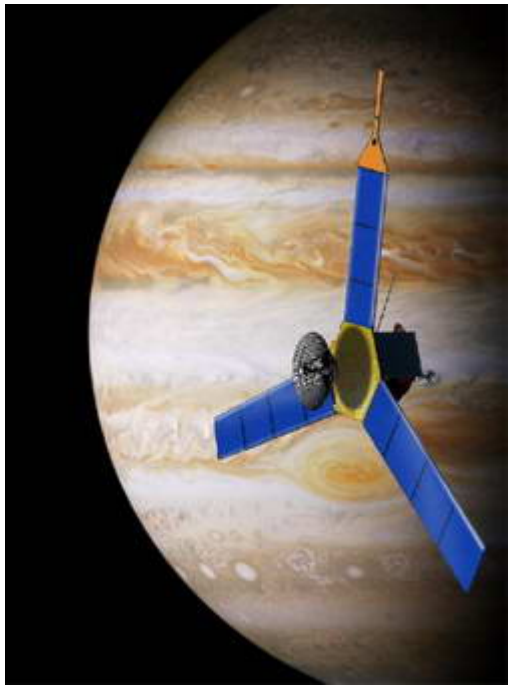
1st NF mission
New Horizons:

Pluto-Kuiper Belt

Launched January 2006
Flyby July 14, 2015
PI: Alan Stern (SwRI-CO)

2nd NF mission
Juno:

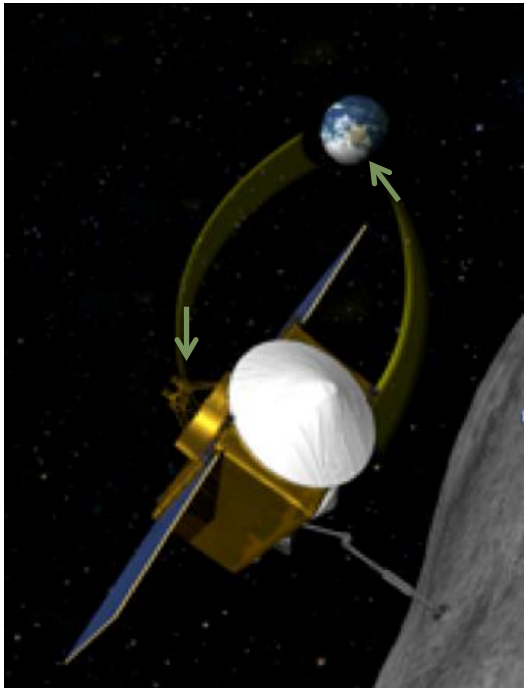
Jupiter Polar Orbiter



Launched August 2011
Arrived July 4, 2016
PI: Scott Bolton (SwRI-TX)

3rd NF mission
OSIRIS-REx:

Asteroid Sample Return

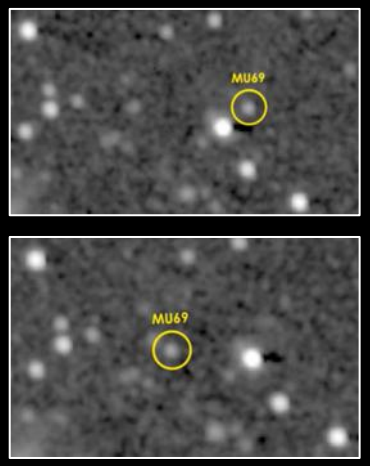


Launched September 2016
PI: Dante Lauretta (UA)

New Horizons

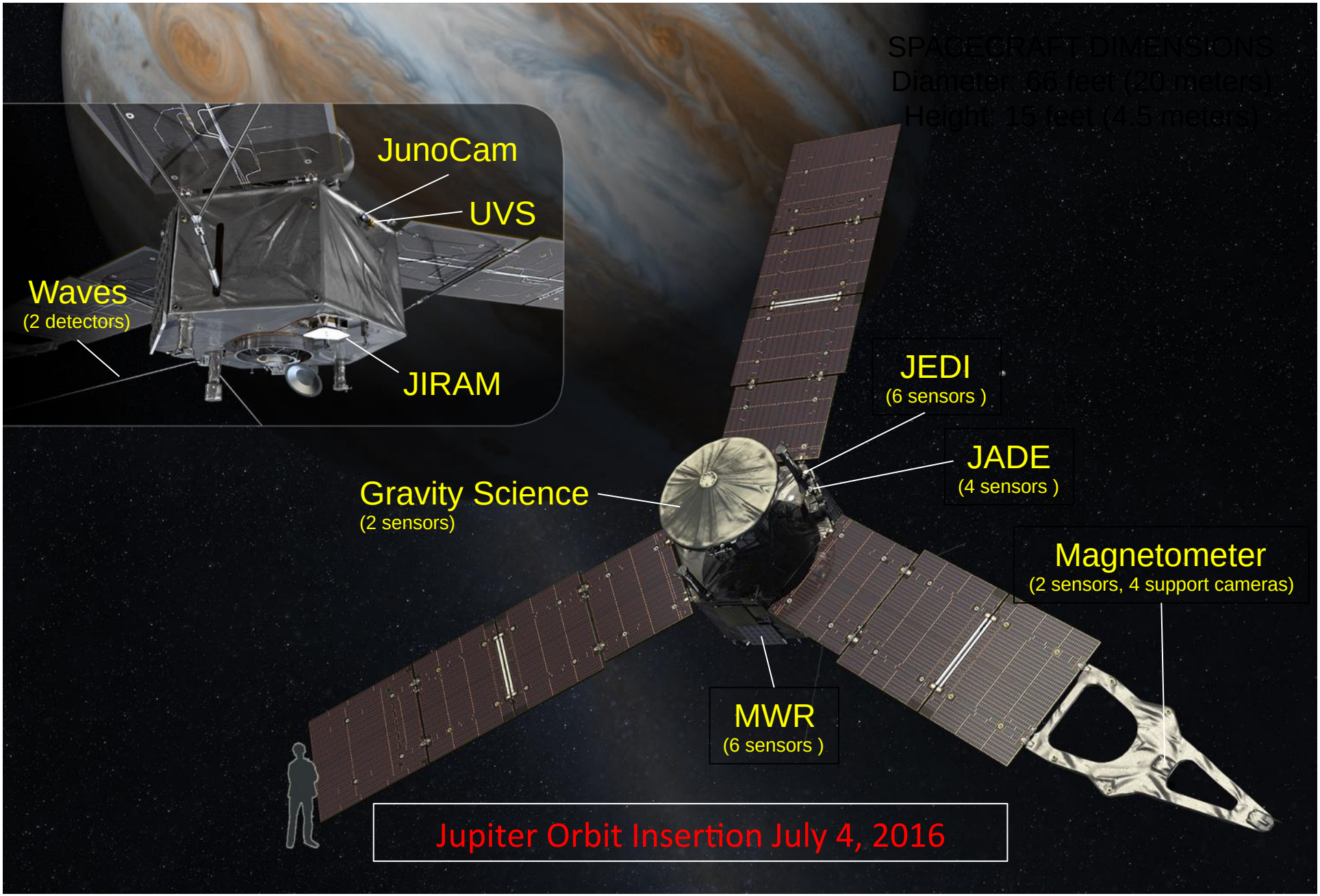
Pluto's Rotation
Charon's Orbit Period
153.36 hours

MU69 Next KBO Target

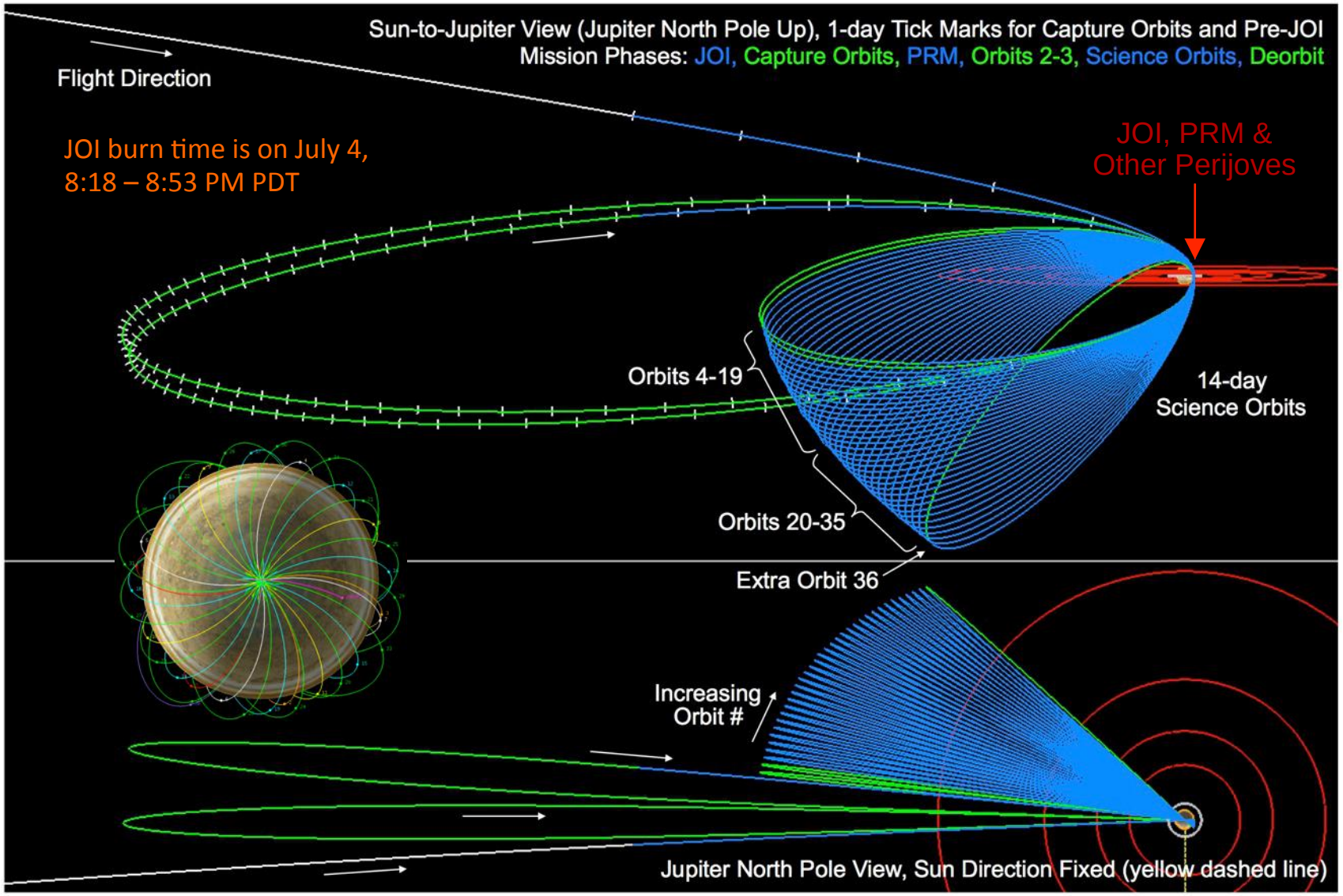


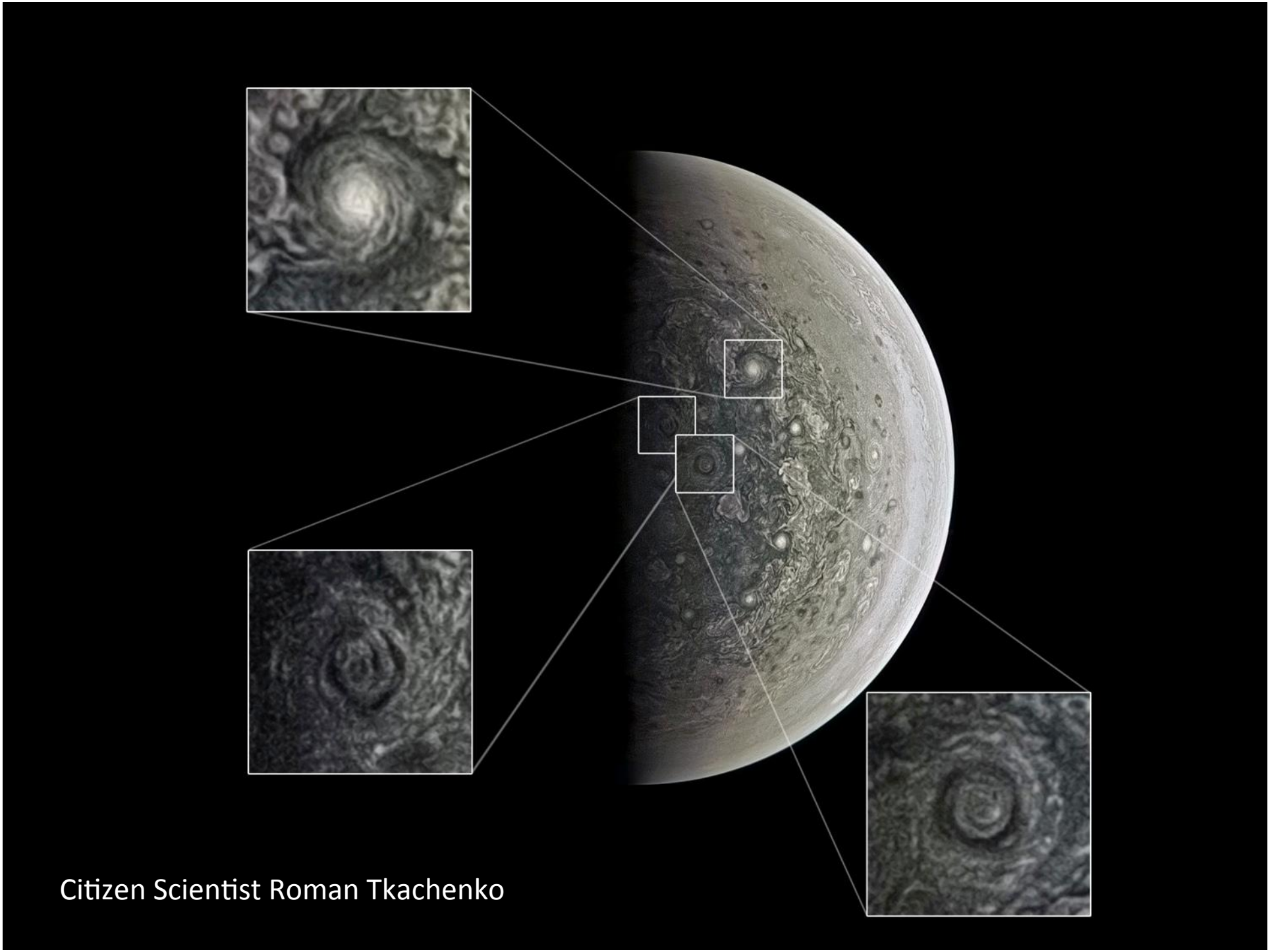
Size ~30 miles

Juno Spacecraft and Payload



Orbital Trajectory

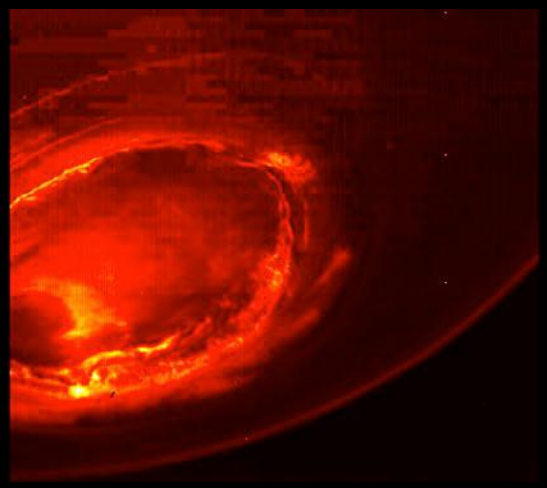



Citizen Scientist Roman Tkachenko

Jupiter's Glow in Infrared Light

2016-08-25T12:54:43

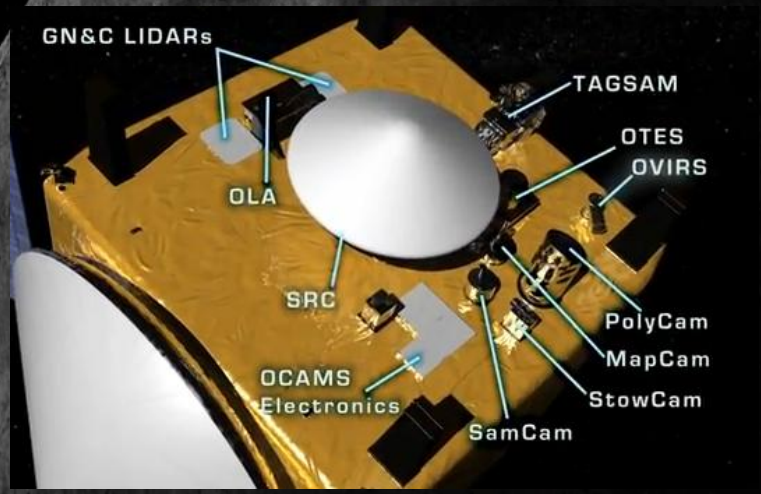
South Pole Aurora

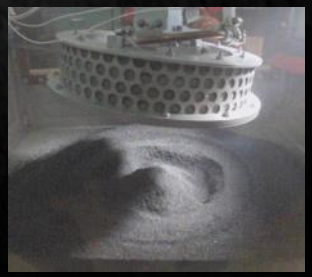


OSIRIS-REx

- Return and analyze a sample of Bennu's surface
- Map the asteroid & document the sample site
- Measure the Yarkovsky effect

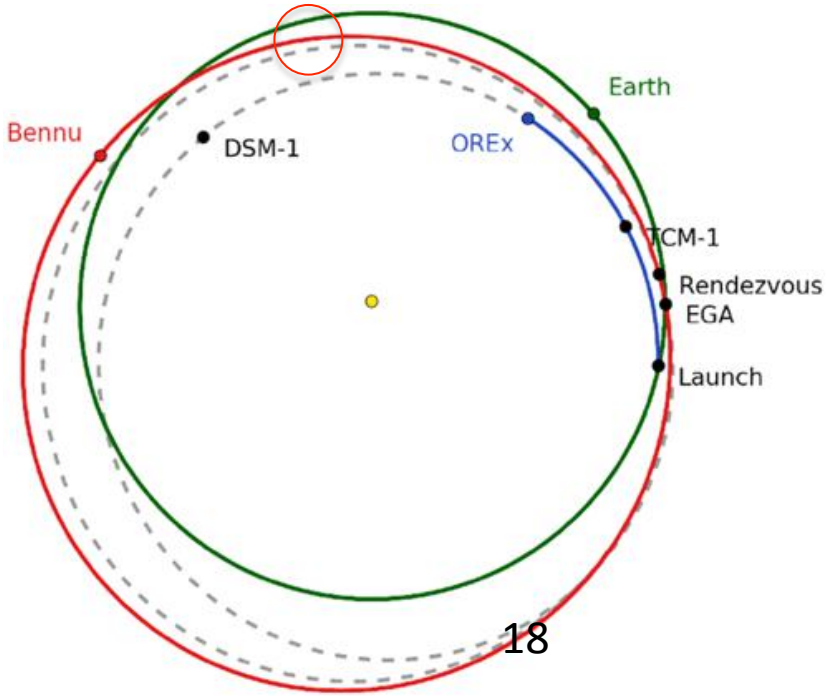
Launched Sept 2016

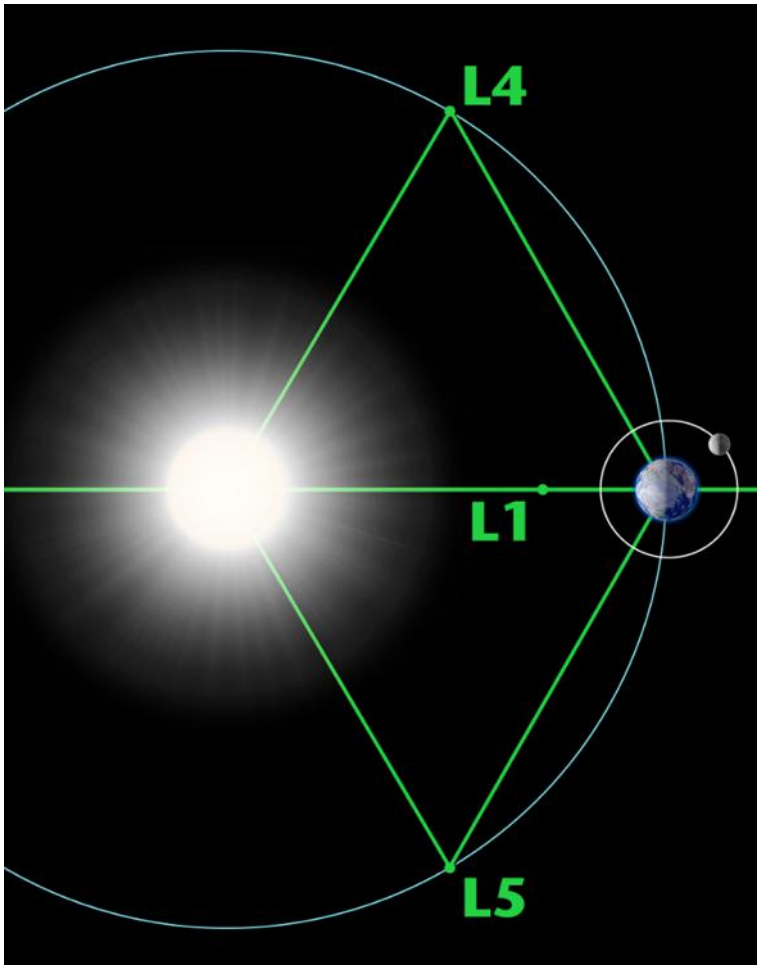




OSIRIS-REx

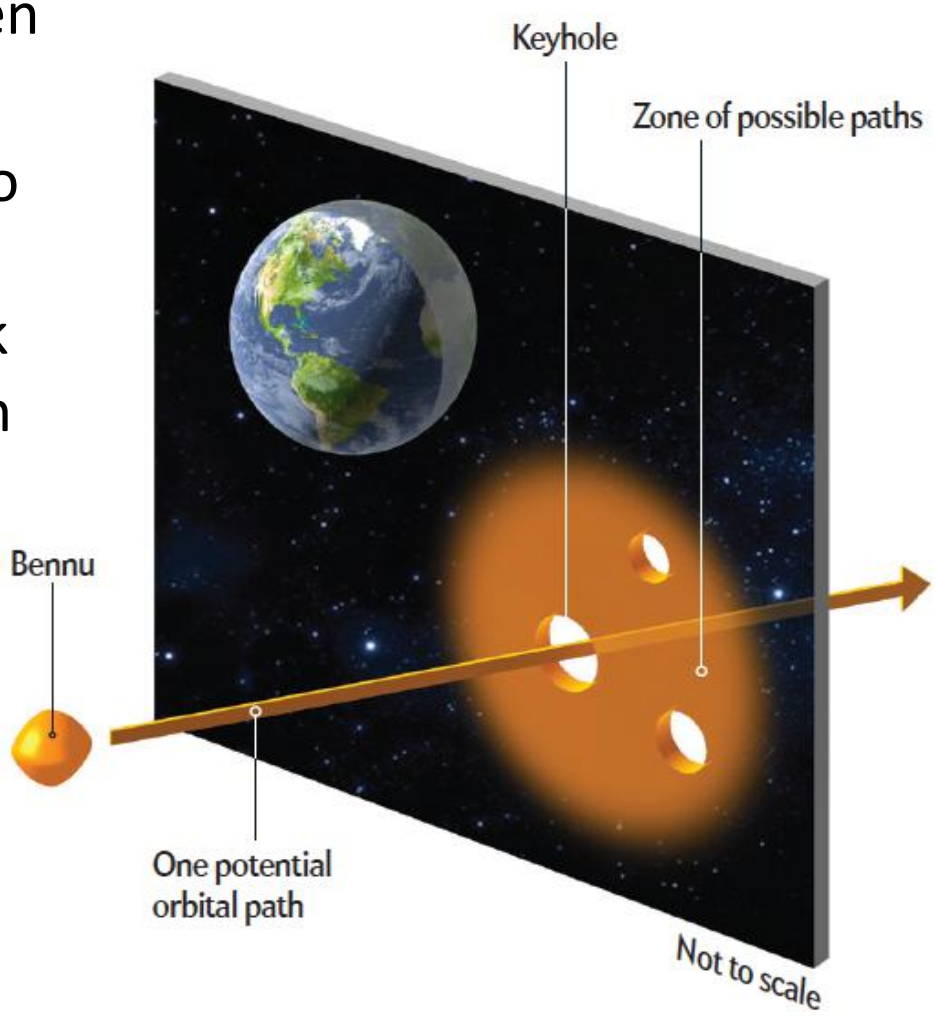
- Flight data as of 1300 UTC on Nov 10:
  - Distance from Earth: 25.4 M miles
  - One way light time: 2 min 16.3 sec
  - Distance to Bennu: 133.0M miles
- Feb 8-20, the OSIRIS-REx spacecraft will activate its onboard camera suite and commence a search for Earth-Trojan asteroids at L4 – a good test of the system

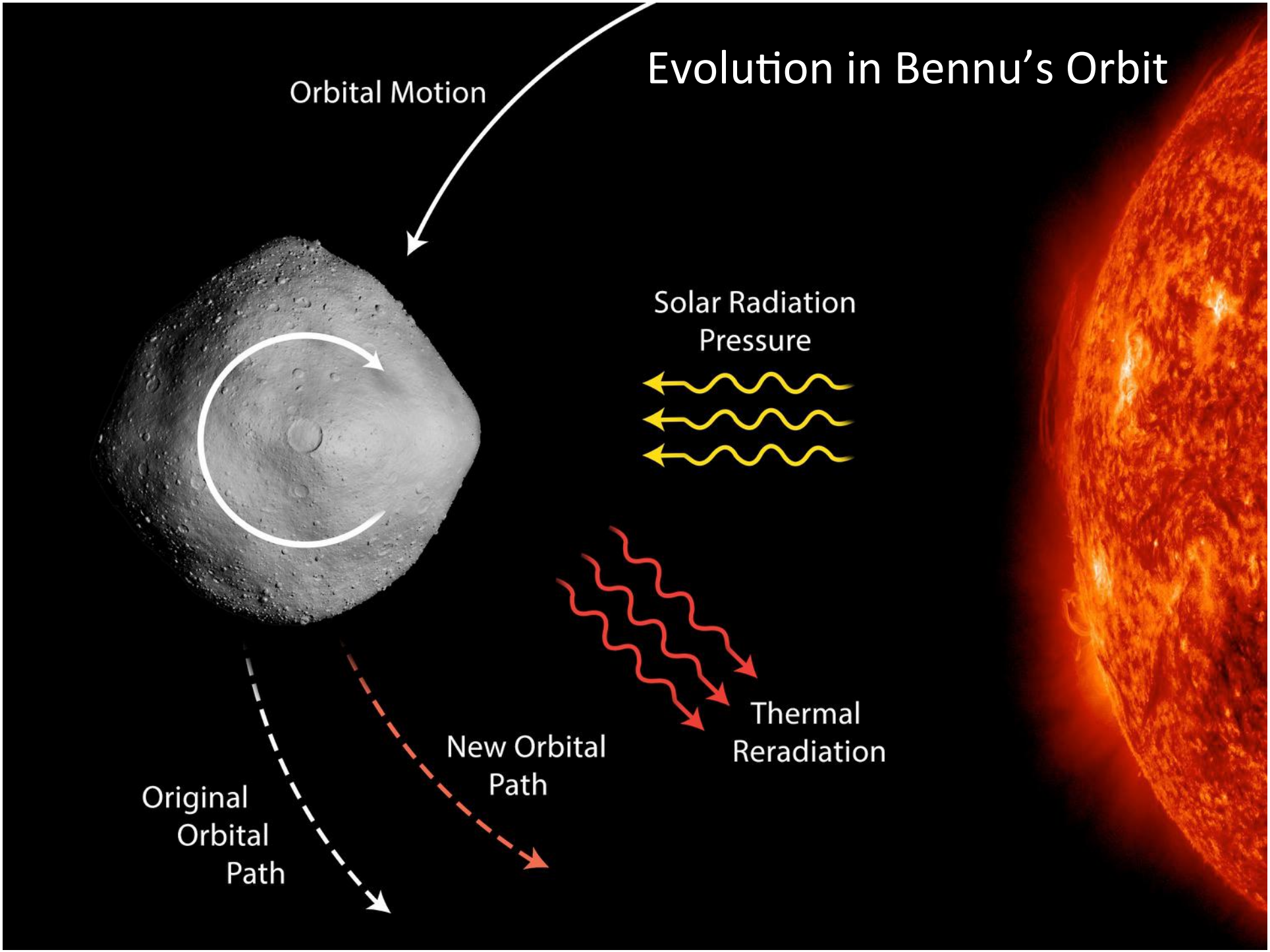




Bennu as a Potential Hazardous Object

- In 2135 Bennu will pass between the Earth and the Moon
- During that encounter it may go through a “keyhole” in which the Earth’s gravity would tweak Bennu’s trajectory and put it on a collision course with Earth
- OISIRS-REx will clarify the sources of instabilities in Bennu’s orbit



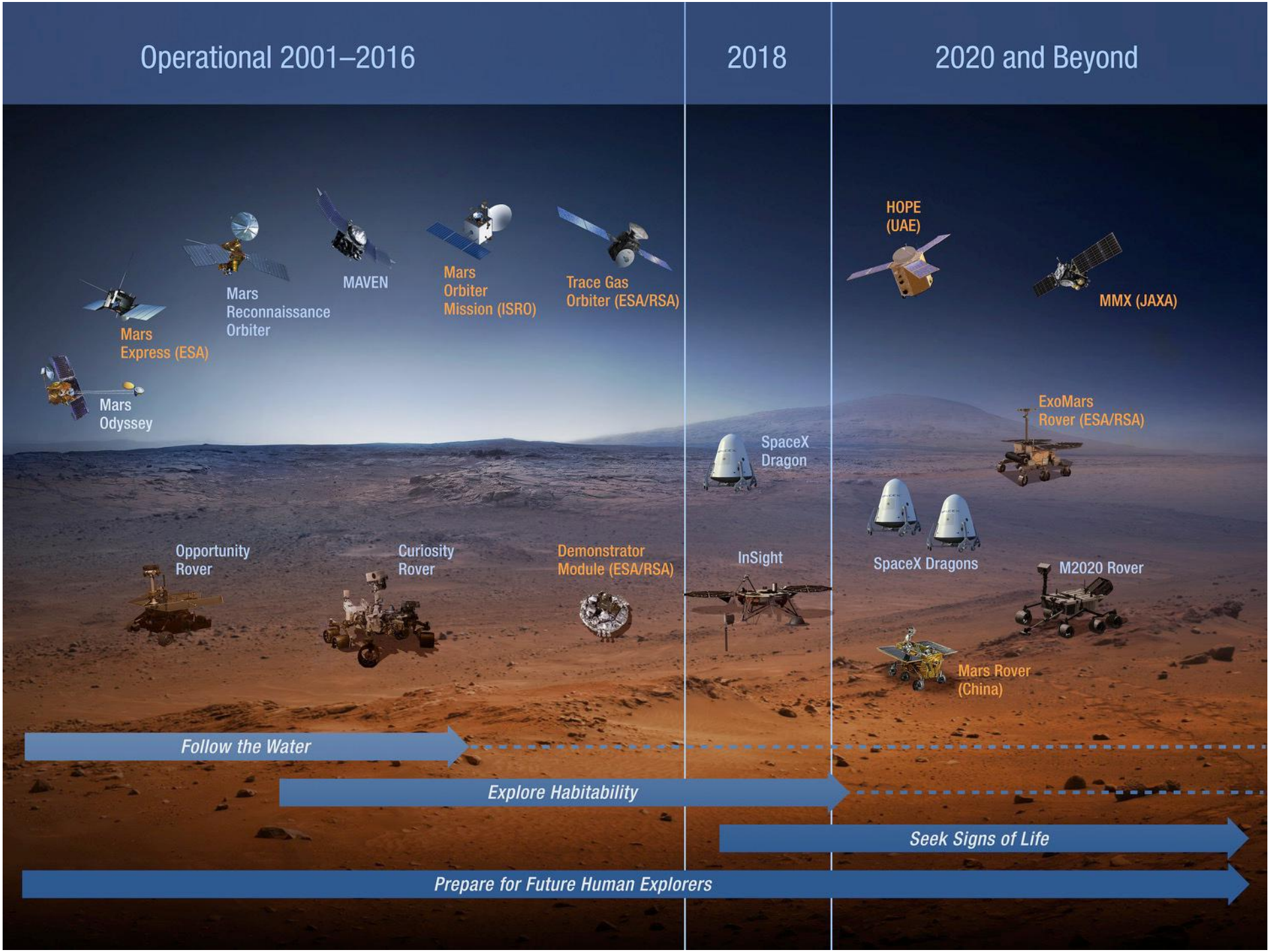

Evolution in Bennu's Orbit
Orbital Motion
Solar Radiation Pressure
Thermal Reradiation
New Orbital Path
Original Orbital Path

Next New Frontiers Program AO

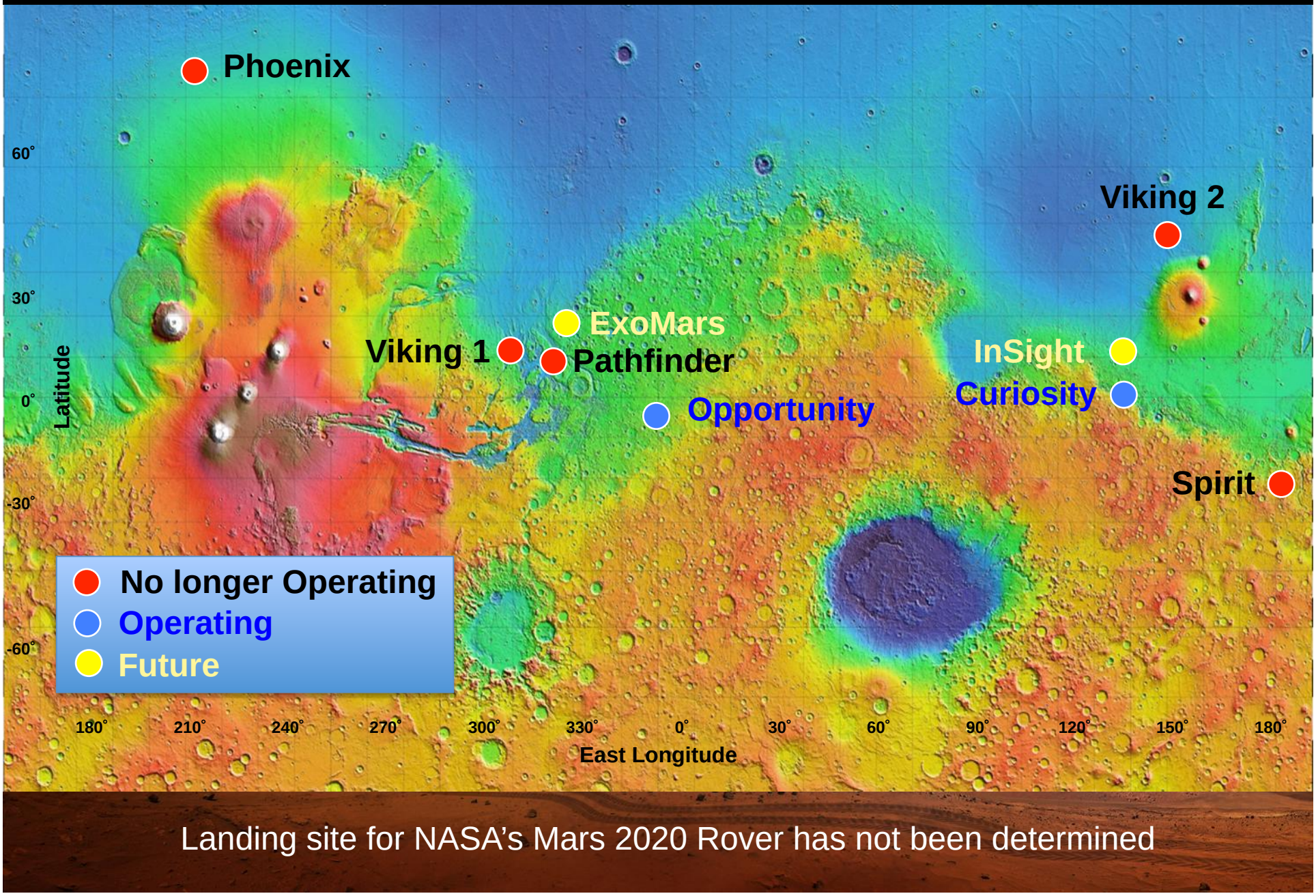
Investigations (listed without priority):

- Comet Surface Sample Return
- Enceladus
- Lunar South Pole-Aitken Basin Sample Return
- Saturn Probe
- Titan
- Trojan Tour and Rendezvous
- Venus In Situ Explorer

Release of final AO..... December 9, 2016
Preproposal Conference ..... January 20, 2016
Electronic Proposal Submittal Deadline..... April 28, 2017
Step-1 Selections Announced (target)..... November 2017
Phase A Concept Study Reports due..... December 2018
Downselection for Flight (target)..... July 2019 (target)
Launch Readiness Date..... NLT Dec. 31, 2025

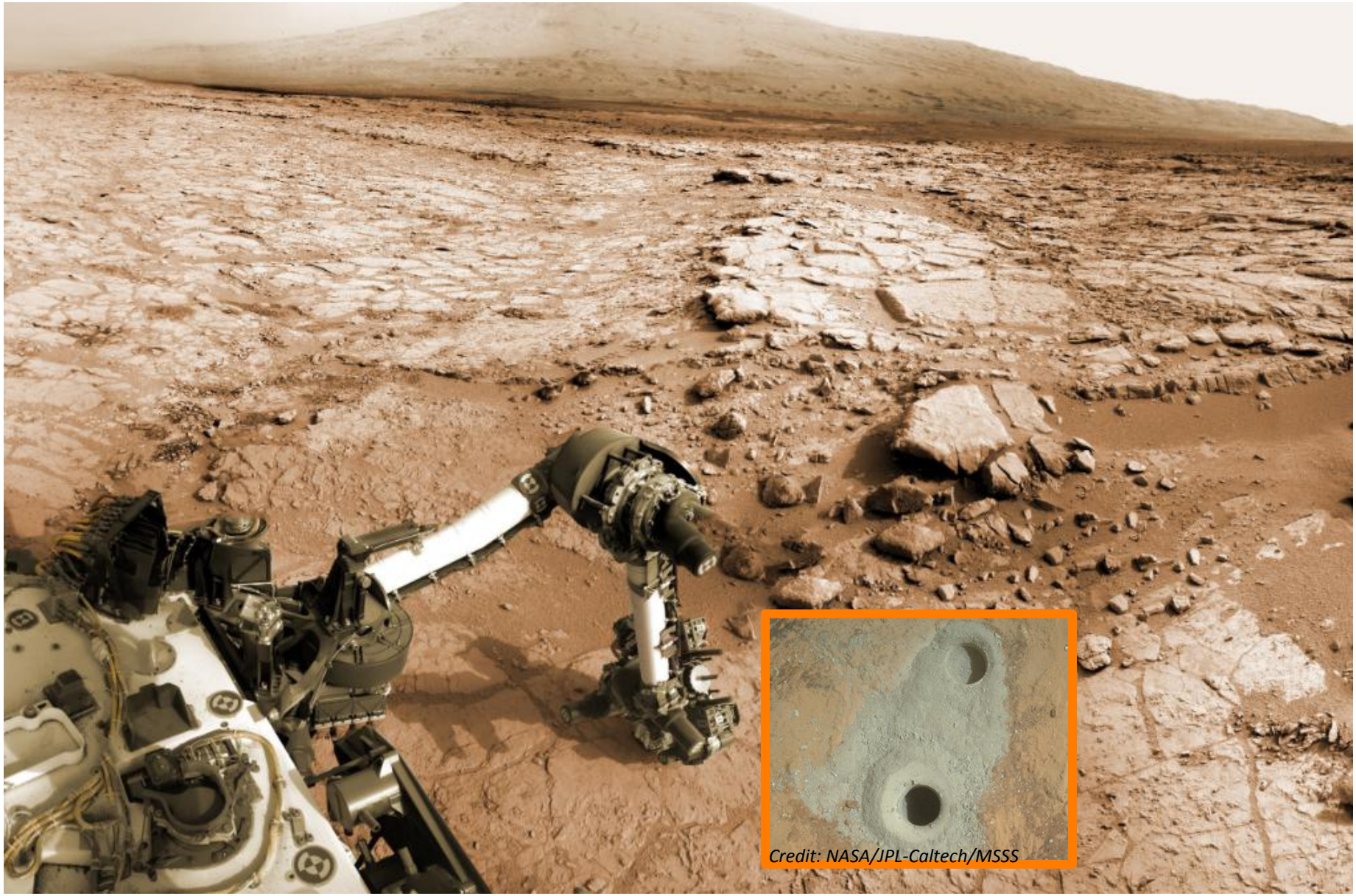

Operational 2001–2016
2018
2020 and Beyond
Mars Express (ESA)
Mars Reconnaissance Orbiter
MAVEN
Mars Orbiter Mission (ISRO)
Trace Gas Orbiter (ESA/RSA)
Mars Odyssey
HOPE (UAE)
MMX (JAXA)
ExoMars Rover (ESA/RSA)
SpaceX Dragon
SpaceX Dragons
Opportunity Rover
Curiosity Rover
Demonstrator Module (ESA/RSA)
InSight
M2020 Rover
Mars Rover (China)
Follow the Water
Explore Habitability
Seek Signs of Life
Prepare for Future Human Explorers

Location of the Landers & Rovers



Landing site for NASA's Mars 2020 Rover has not been determined

An Ancient Habitable Environment

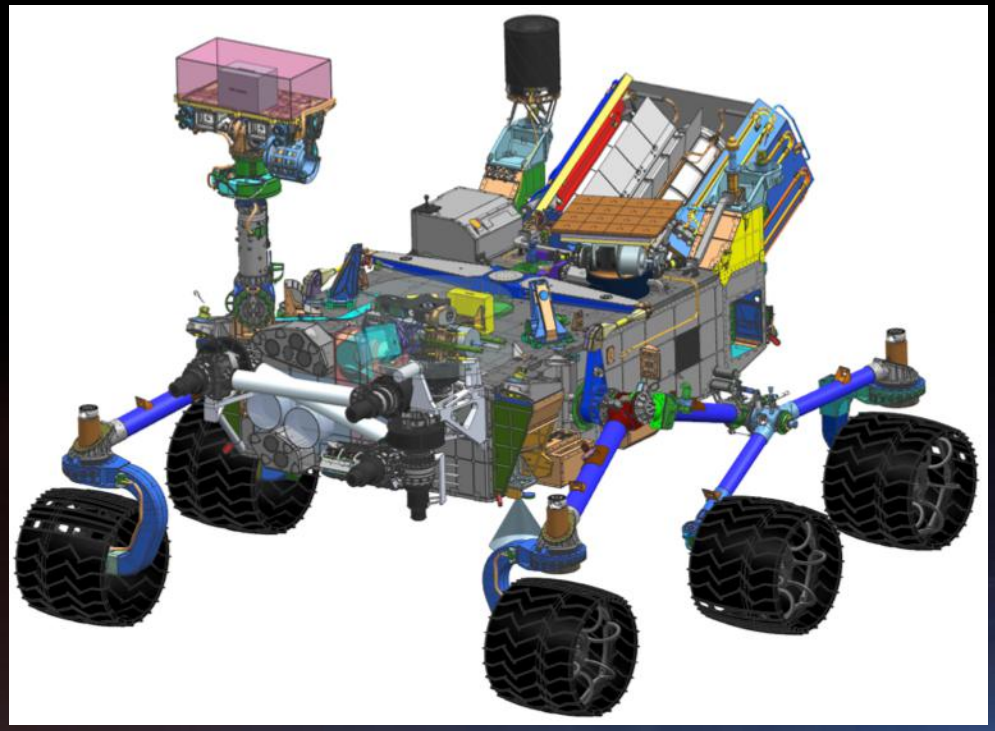


Seeking signs of life: Mars 2020 Rover

Conduct rigorous *in situ* science

Geologically diverse site of ancient habitability

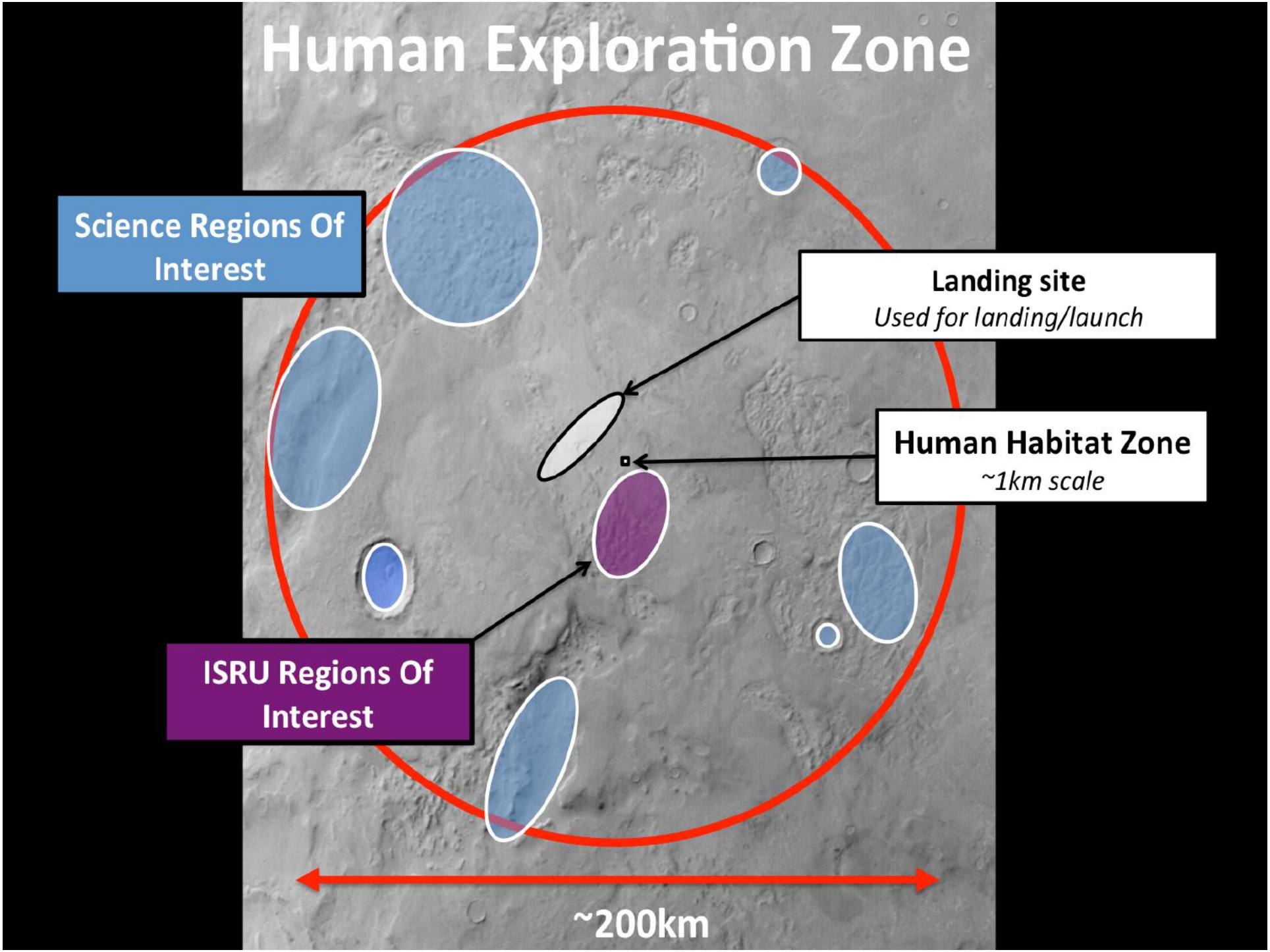
Coordinated, nested context and fine-scale measurements



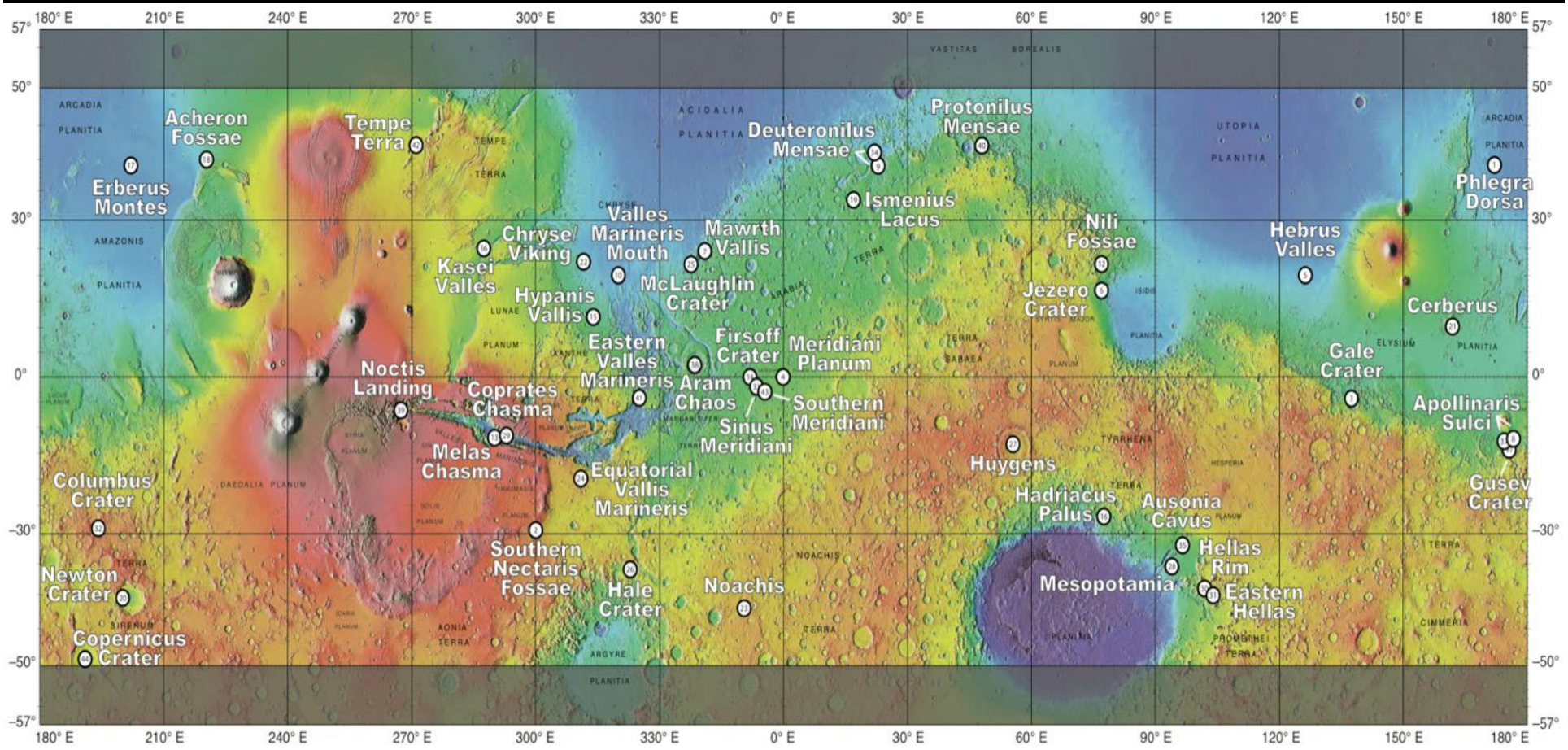
Enable the future

Critical ISRU and technology demonstration required for future Mars exploration

Returnable cache of samples

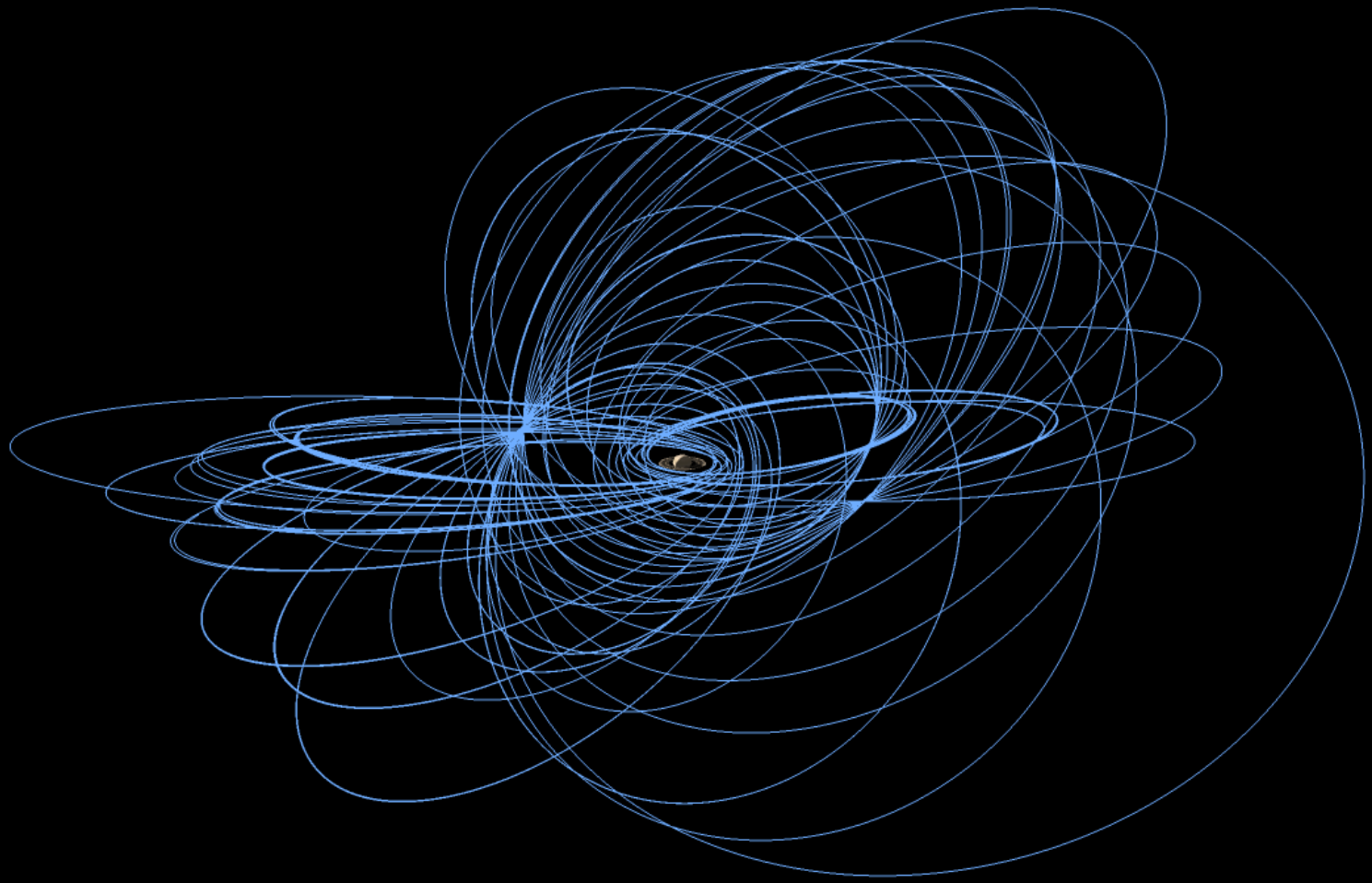

Human Exploration Zone
Science Regions Of Interest
Landing site
Used for landing/launch
Human Habitat Zone
~1km scale
ISRU Regions Of Interest
~200km

Potential Exploration Zones

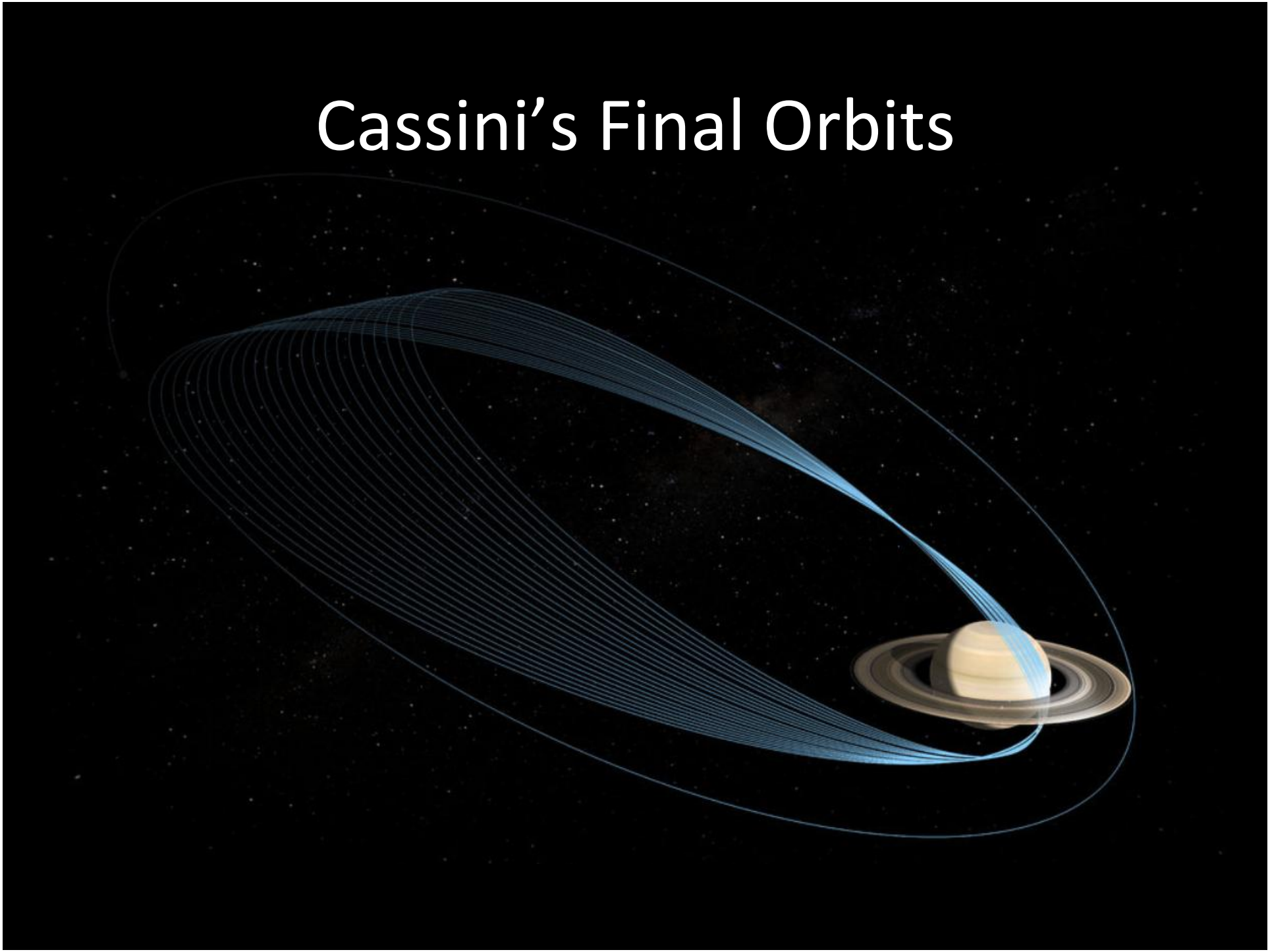


Outer Planets Program

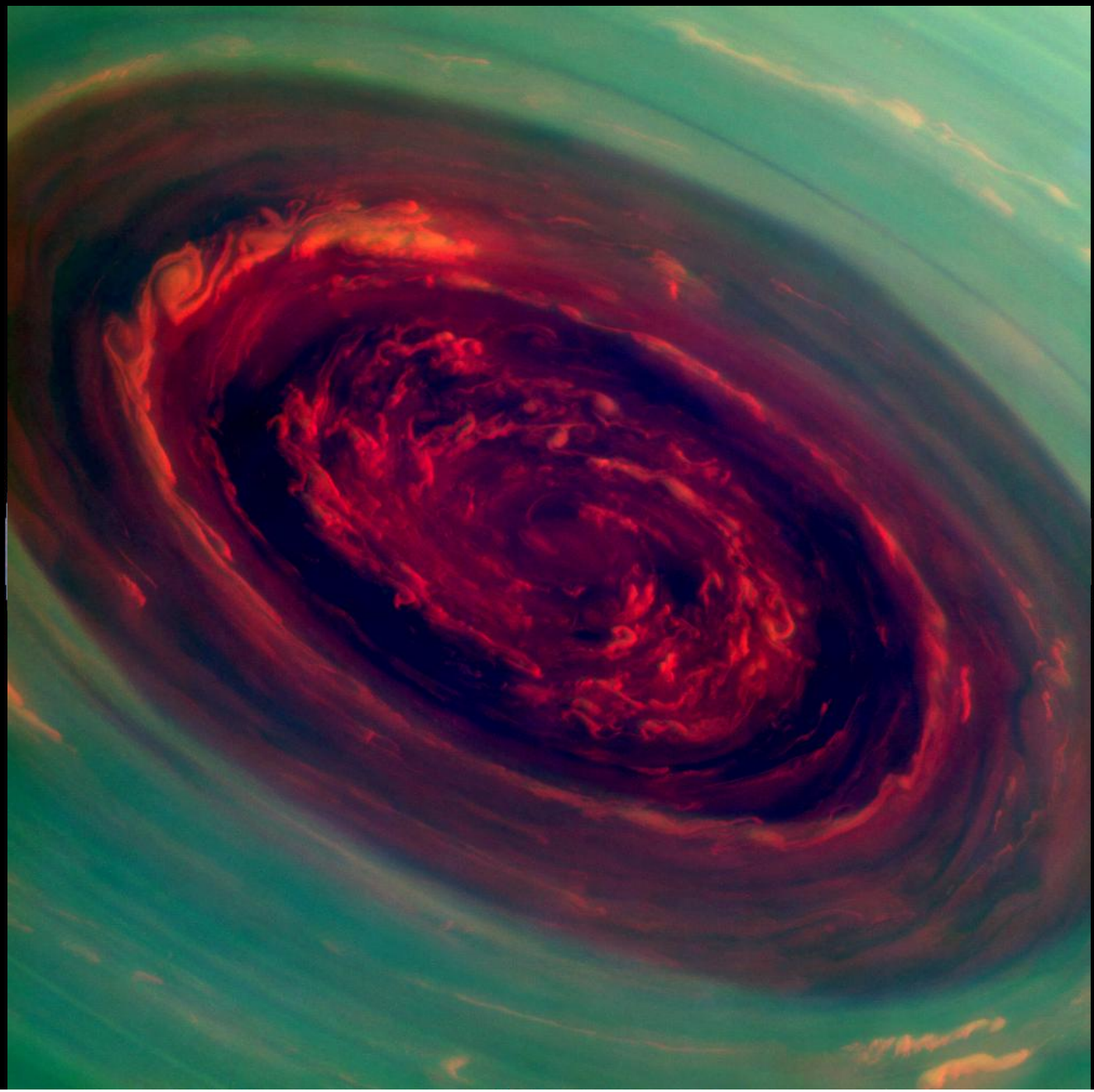
Cassini's Orbits (2004-Present)



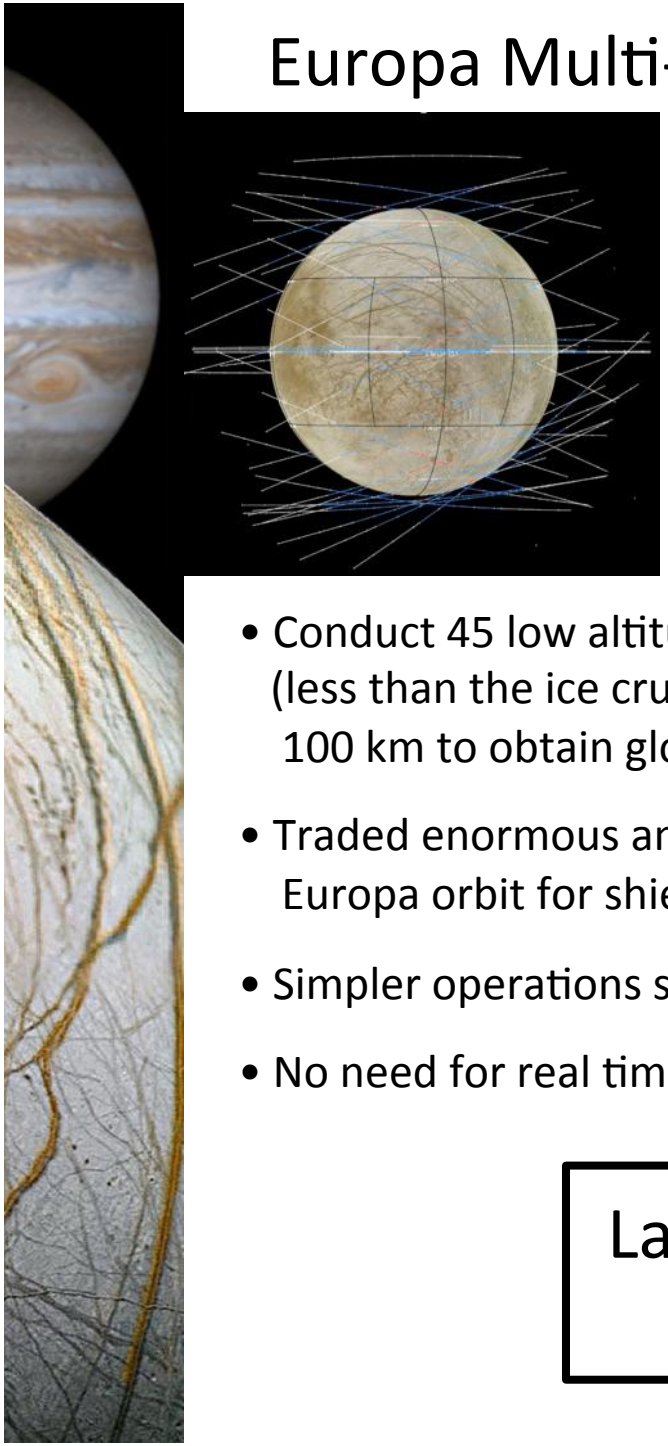
Cassini's Final Orbits



Saturn’s Giant Hurricanes

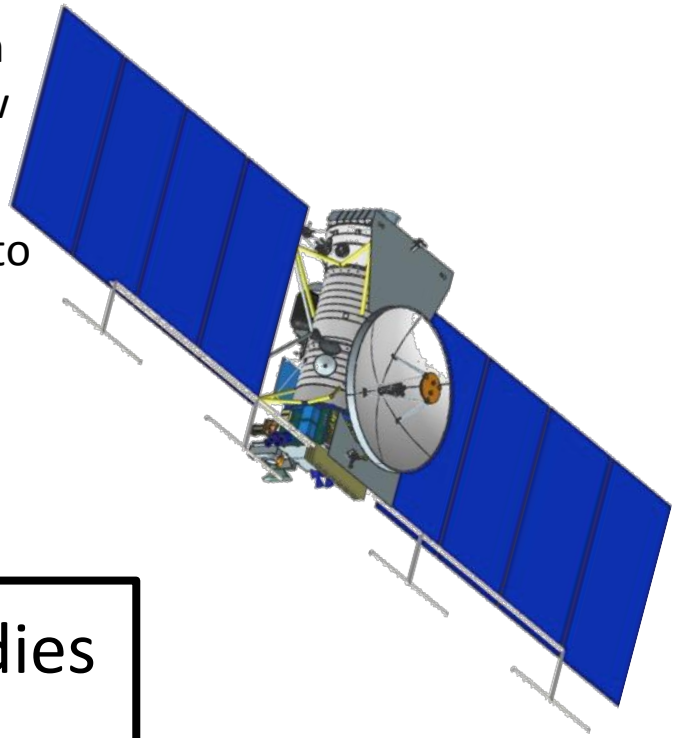


Europa Multi-Flyby Mission Concept Overview



Science	
Objective	**Description**
Ice Shell & Ocean	Characterize the ice shell and any subsurface water, including their heterogeneity, and the nature of surface-ice-ocean exchange
Composition	Understand the habitability of Europa's ocean through composition and chemistry.
Geology	Understand the formation of surface features, including sites of recent or current activity, and characterize high science interest localities.
Recon	Characterize scientifically compelling sites, and hazards for a potential future landed mission to Europa

- Conduct 45 low altitude flybys with lowest 25 km (less than the ice crust) and a vast majority below 100 km to obtain global regional coverage
- Traded enormous amounts of fuel used to get into Europa orbit for shielding (lower total dose)
- Simpler operations strategy
- No need for real time down link



Lander Concept Studies Are Continuing

Near Earth Objects Program

Planetary Defense Coordination Office

Administrator
Associate Administrator

Associate Administrator,
Science Mission Directorate

Planetary Science Division
Program Director

Lead Program Executive
Planetary Defense Officer

Public Communications

Policy Development

NEO Observation Program
Program Manager
Program Scientist

- Minor Planet Center/IAWN
- Center for NEO Studies @ JPL
- Catalina Sky Survey
- Pan-STARRS
- LINEAR/SST
- IRTF
- GSSR
- NEOWISE
- ……..

Legacy Program (1998)

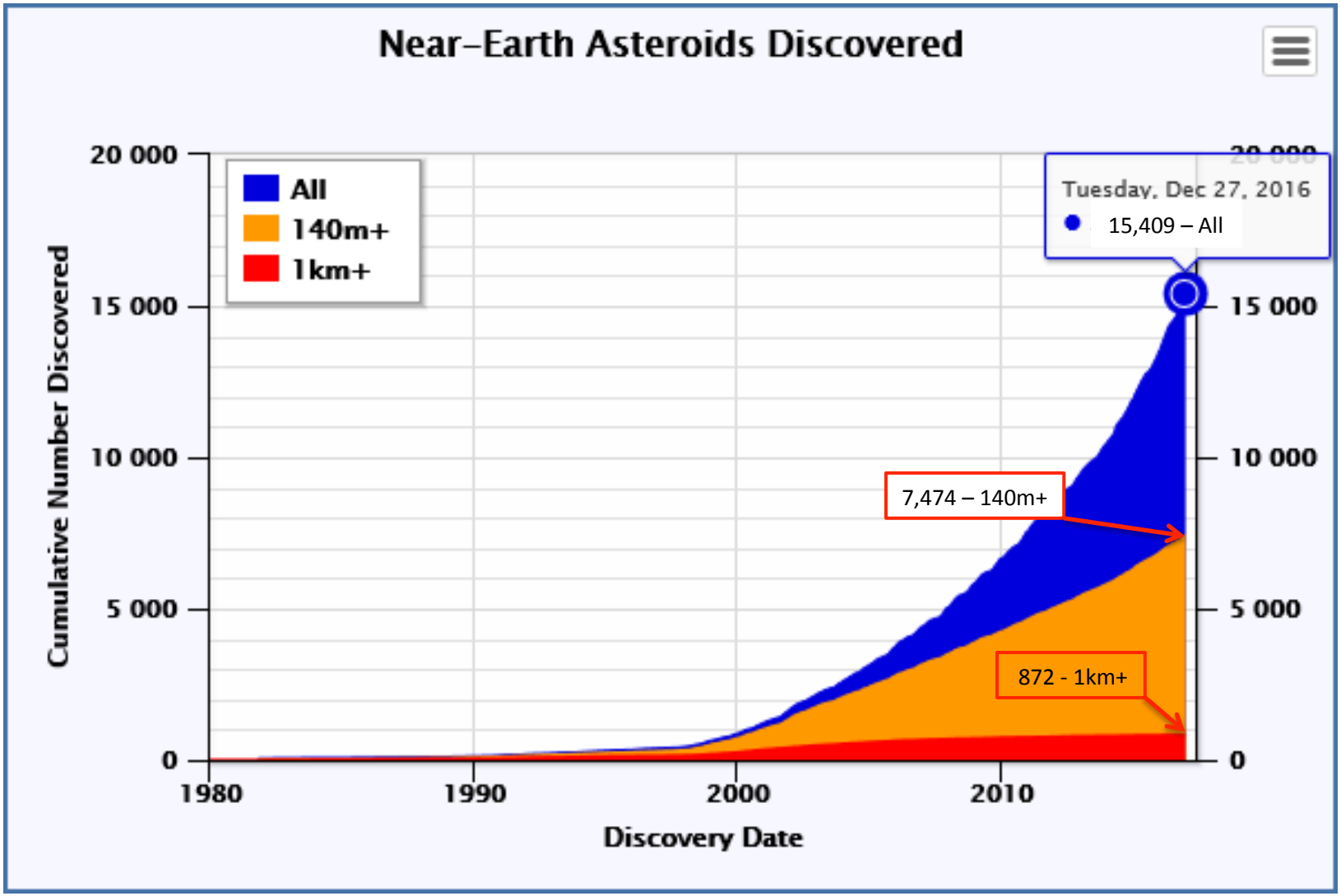
Interagency and
Emergency Response
Program Officer(s)

- Interagency coordination
- Emergency Response planning
- Interagency exercise

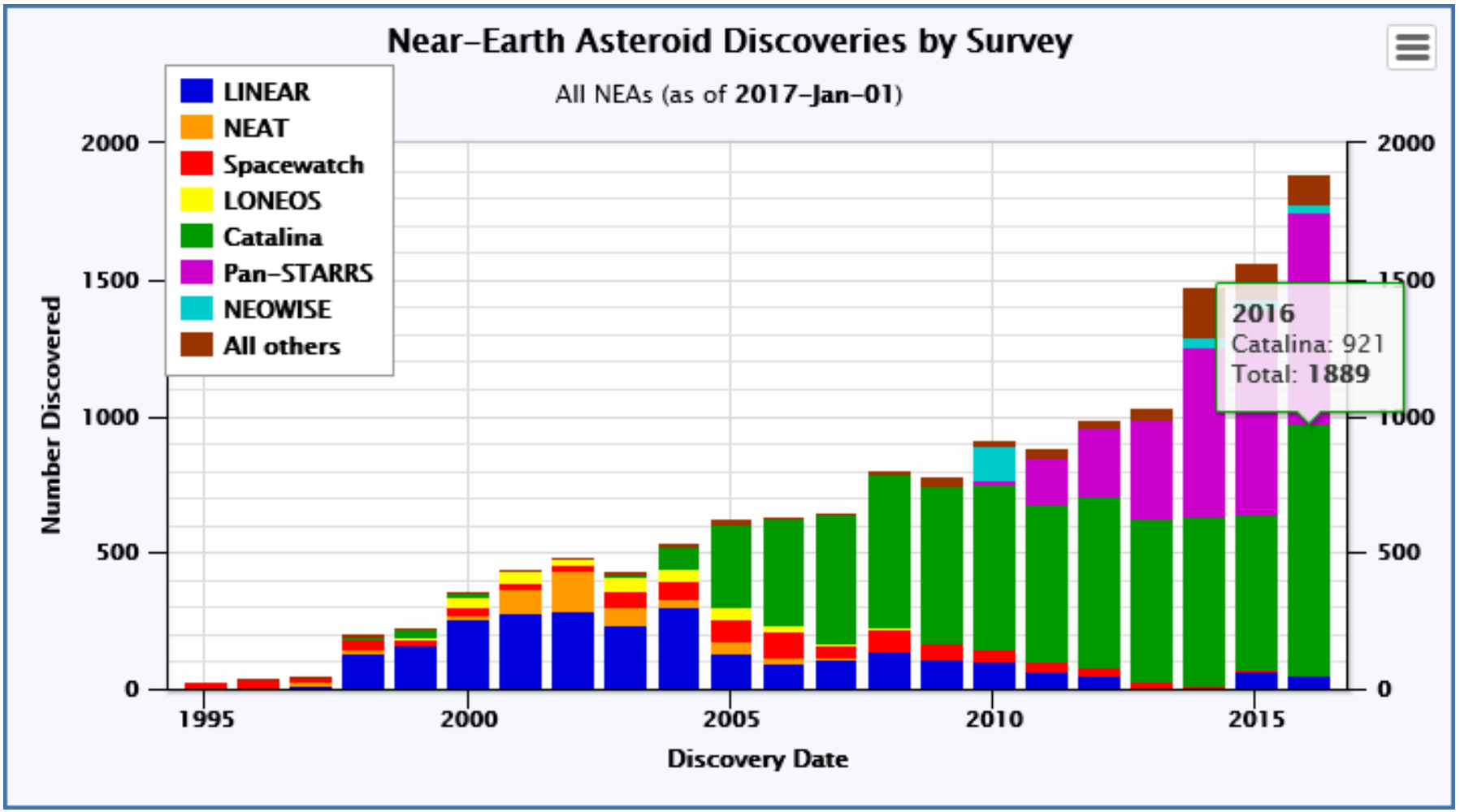
Mitigation Research
Program Officer(s)

- SMPAG
- ARM Gravity Tractor Demo
- AIDA
- Short Warning Mitigation
- ……..

NEA Survey Status

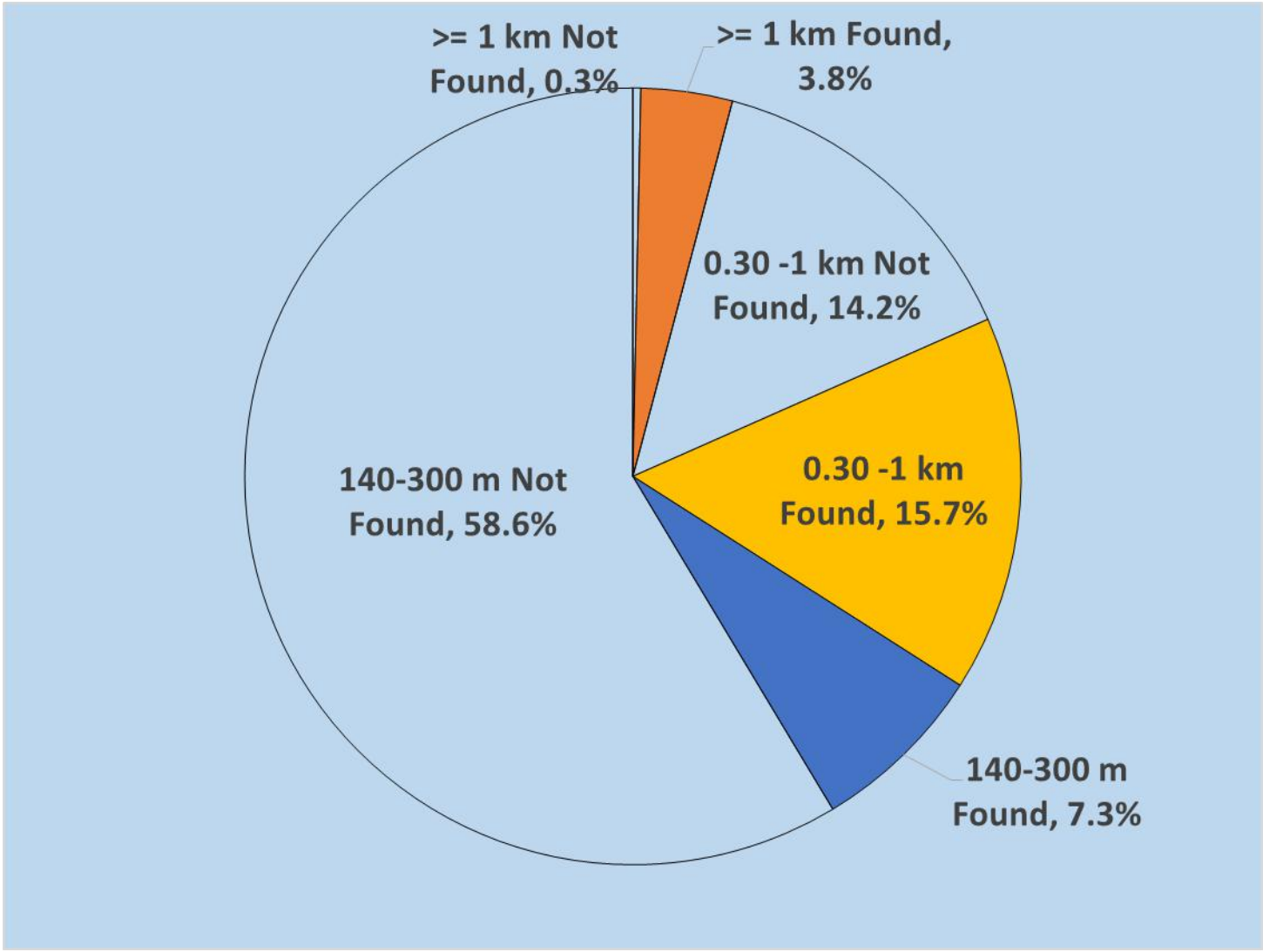


NEA Survey Rate – All Sizes



Near Earth Asteroid Survey Status

If Population 140 meters and greater is ~ 25,500 = 100%

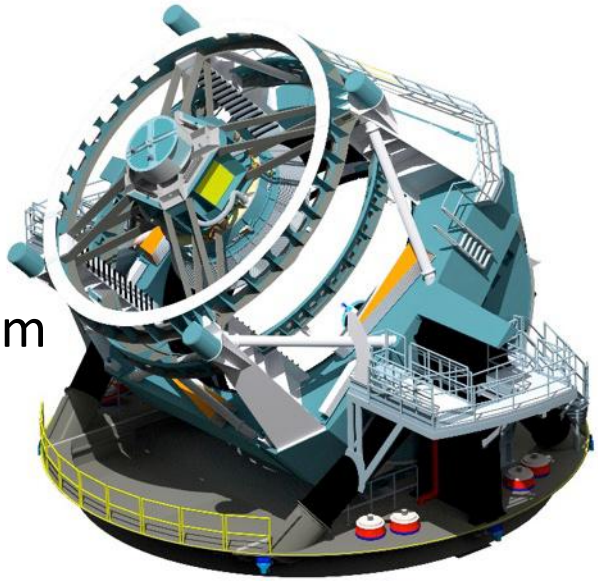


LSST NEO Survey Study

- Jointly sponsored by NASA - NSF to reach consensus position on benefits
- Participation by JPL CNEOS and LSST solar system science team
- Will inform how LSST data could be integrated into NEOO Program

Status

- Analysis completed and final report in draft
- Still needs review by Independent Review Team
- Then vetting by NASA - NSF sponsors
- Expect completion in two months

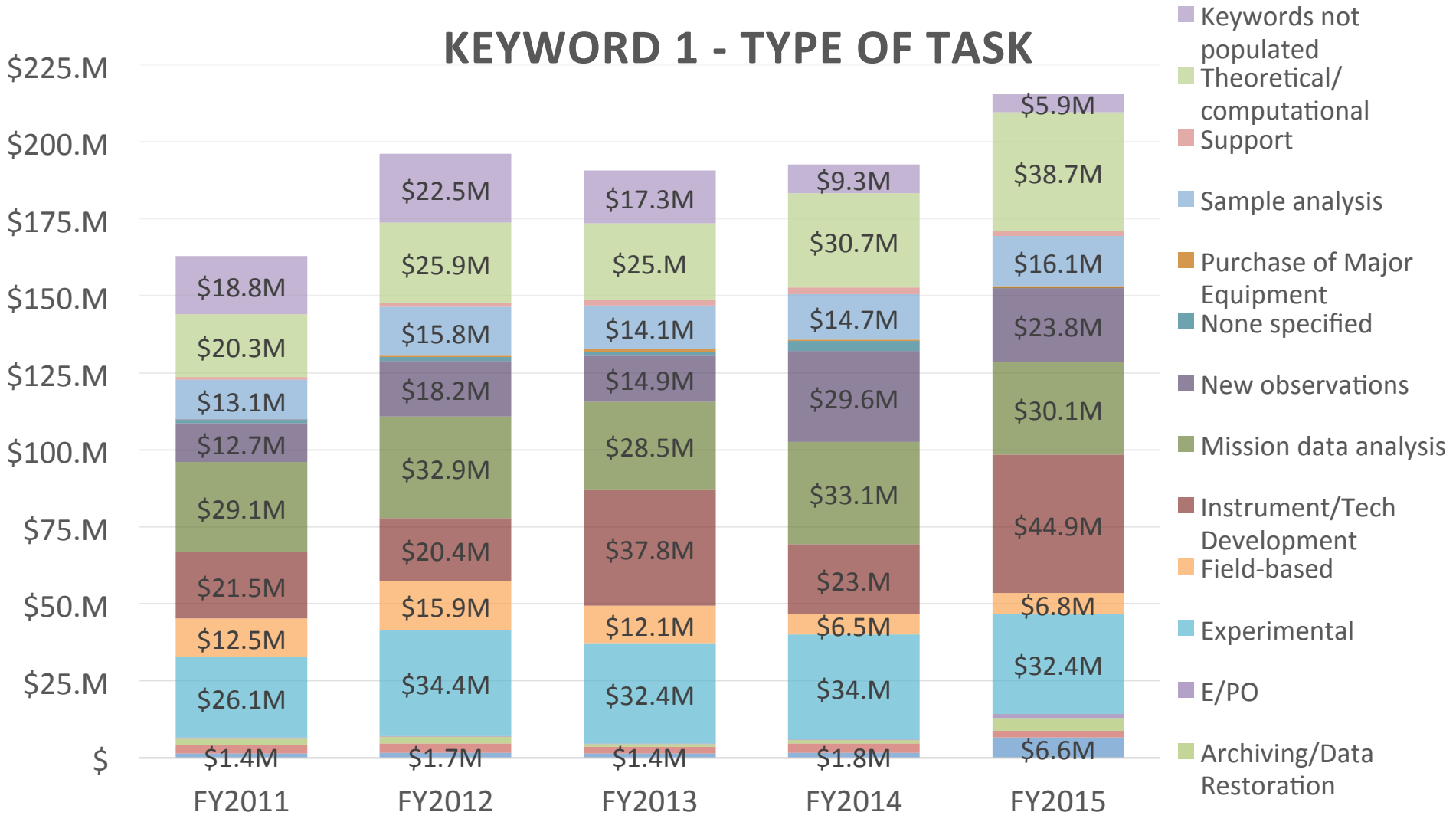


Research and Analysis Program

Program Name	Step-2 Due Date	Number of Step 2	Number Selected	Percent Selected
Exoplanets (XRP)*	05/26/2016	110	13 (9)	20%
Emerging Worlds (EW)	06/03/2016	155	29	19%
Cassini Data Analysis (CDAPS)	06/16/2016	66	13	20%
Solar System Obs (SSO)	06/10/2016	90	27	30%
MatISSE	06/21/2016	60	pending	
Lab Analysis of Returned Samples (LARS)	06/24/2016	28	11	39%
Planetary Data Archiving, Resto, Tools (PDART)	07/15/2016	89	21	24%
Exobiology (EXOB)	07/22/2016	173	pending	
Concepts for Ocean Worlds Life Detection Tech (COLDTech)	08/12/2016	83	16	19%
Planetary Protection Research (PPR)	09/02/2016	n/a	n/a	
Planetary Sci./Tech. Through Analog Research (PSTAR)	09/23/2016	50	pending	
Mars Data Analysis (MDAP)	09/30/2016	118	pending	
Lunar Data Analysis (LDAP)	10/28/2016	48	pending	
PICASSO	11/14/2016	85	pending	
Discovery Data Analysis (DDAP)	11/17/2016	34	pending	
Hot Operating Temp Tech (HOTTCH)	11/23/2017	29	7	24%
Habitable Worlds (HW)	01/20/2017	61	pending	
Solar System Workings (SSW)	02/23/2017	pending	pending	

Keyword Analysis

- Analysis of keyword distribution, 2011-2015 for categories:
  - Type of Task (keyword category 1)
  - Object(s) of Study (keyword category 2)
  - Science Discipline (keyword category 3)
- Analysis includes:
  - R&A awards, including NAI CAN awards
  - Data Analysis Programs
  - Participating Scientist and Guest Investigator Programs
- Analysis excludes:
  - Support activities
  - Facilities (e.g. RPIFs, AVGR, GEER, PAL, RELAB, …)
- Caveats
  - If more than one keyword was used within any category, approved amount was equally divided between keywords
  - Return rate varied from year to year, portfolio to portfolio, and keyword category to keyword category
  - Keywords might have been used inconsistently between program officers


KEYWORD 1 - TYPE OF TASK
$225.M
$200.M
$175.M
$150.M
$125.M
$100.M
$75.M
$50.M
$25.M
$
FY2011
FY2012
FY2013
FY2014
FY2015
$18.8M
$20.3M
$13.1M
$12.7M
$29.1M
$21.5M
$12.5M
$26.1M
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$32.9M
$20.4M
$15.9M
$34.4M
$1.7M
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$28.5M
$37.8M
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$32.4M
$1.4M
$9.3M
$30.7M
$14.7M
$29.6M
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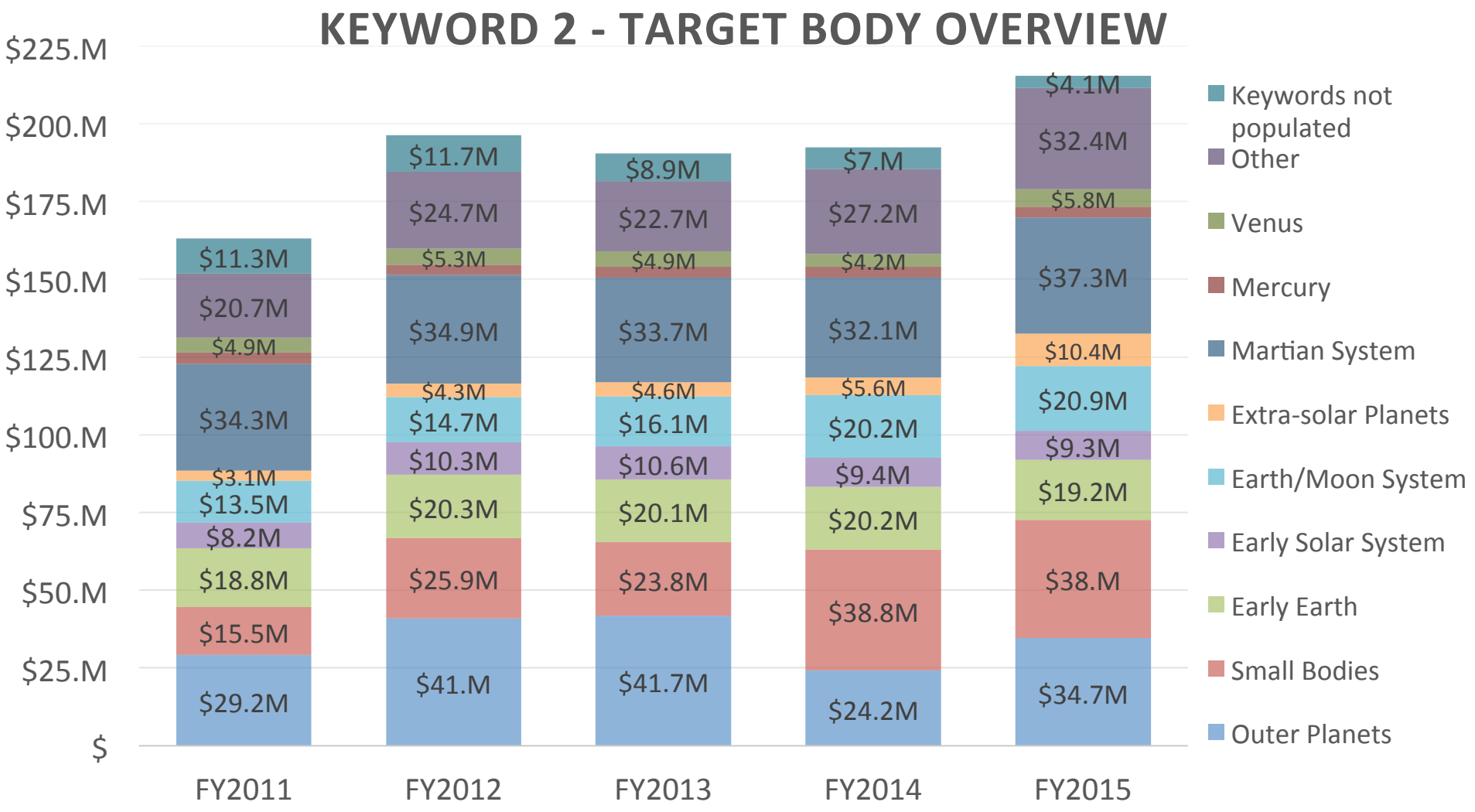
$6.6M
Keywords not populated
Theoretical/ computational
Support
Sample analysis
Purchase of Major Equipment
None specified
New observations
Mission data analysis
Instrument/Tech Development
Field-based
Experimental
E/PO
Archiving/Data Restoration


KEYWORD 2 - TARGET BODY OVERVIEW
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$25.M
$
FY2011
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FY2014
FY2015
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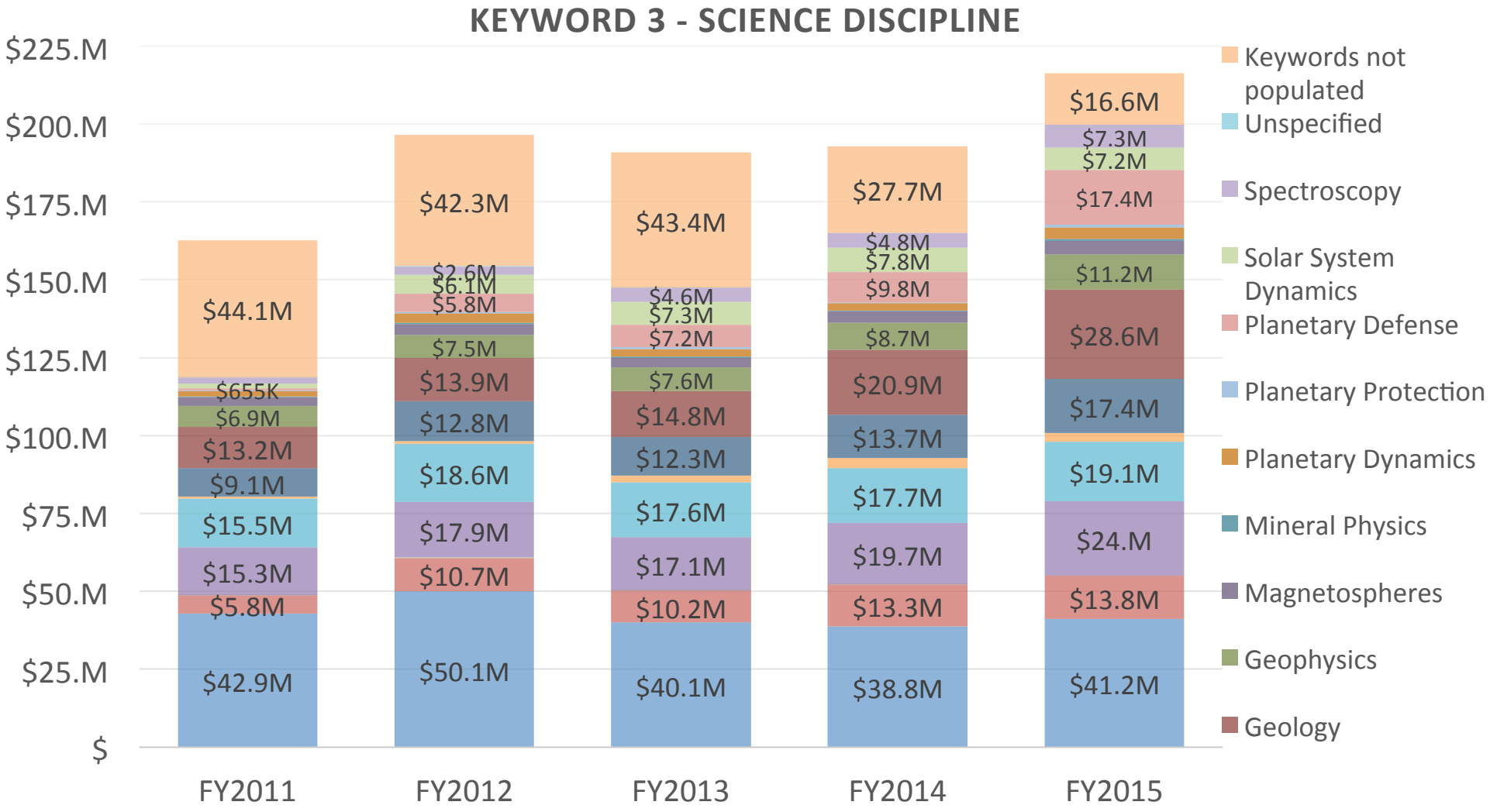
$34.7M
Keywords not populated
Other
Venus
Mercury
Martian System
Extra-solar Planets
Earth/Moon System
Early Solar System
Early Earth
Small Bodies
Outer Planets


KEYWORD 3 - SCIENCE DISCIPLINE
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$25.M
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FY2011
FY2012
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FY2014
FY2015
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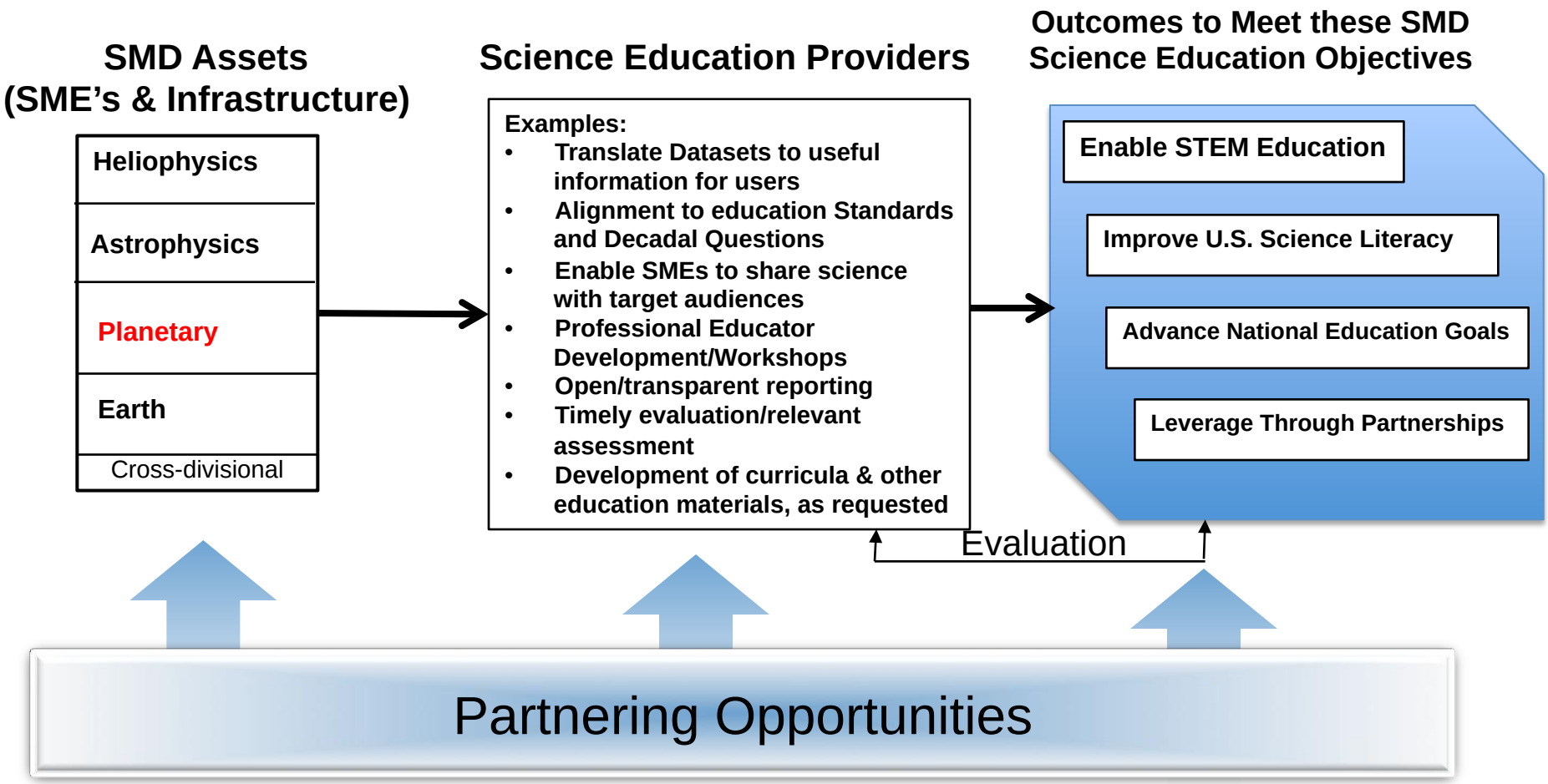
Keywords not populated
Unspecified
Spectroscopy
Solar System Dynamics
Planetary Defense
Planetary Protection
Planetary Dynamics
Mineral Physics
Magnetospheres
Geophysics
Geology

Planetary Science EPO

SMD Science Education Model



Planetary Science Cooperative Agreement Awardees

Arizona State University –Tempe, AZ. Linda Elkins-Tanton, Principal Investigator for "NASA SMD Exploration Connection"

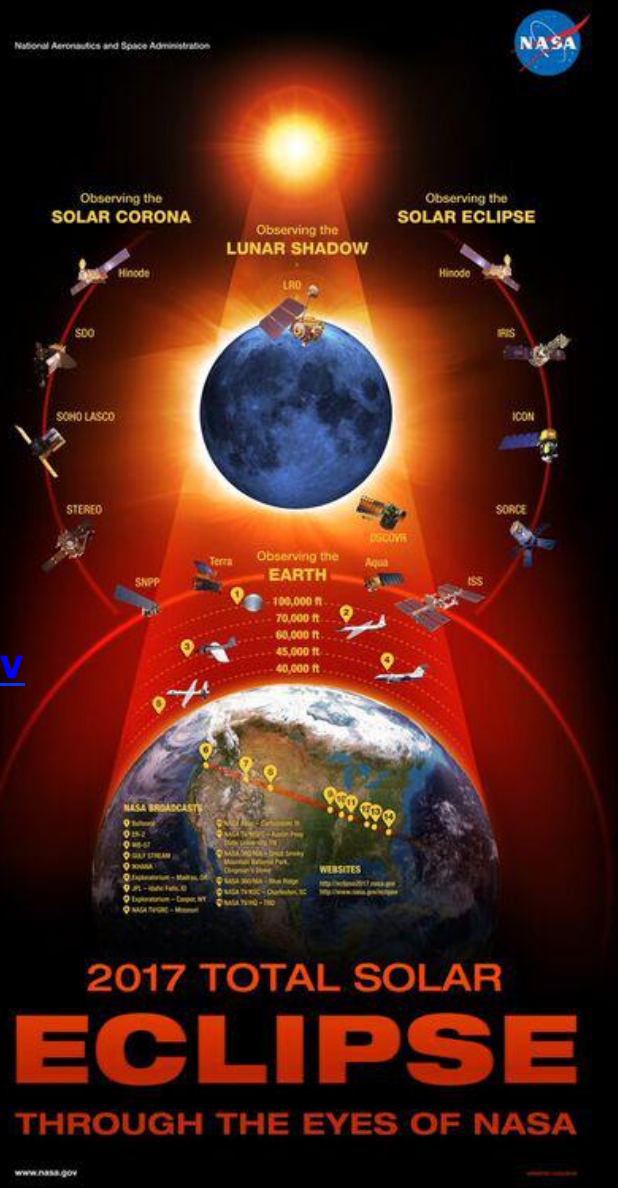
Challenger Center for Space Science Education--Washington, DC Robert Piercey, Principal Investigator for "CodeRed: My STEM Mission"

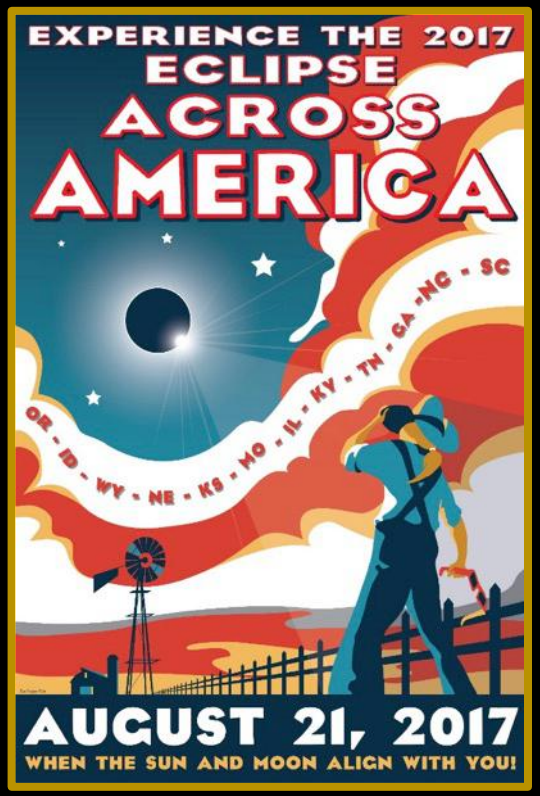
Jet Propulsion Laboratory –Pasadena, CA. Michelle Viotti, Principal Investigator for "NASA Active and Blended Learning Ecosystem (N-ABLE)"

Northern Arizona University—Flagstaff, AZ. Joelle Clark, Principal Investigator for "PLANETS (Planetary Learning that Advances the Nexus of Engineering, Technology, and Science)"

2017 Great American Eclipse on August 21, 2017

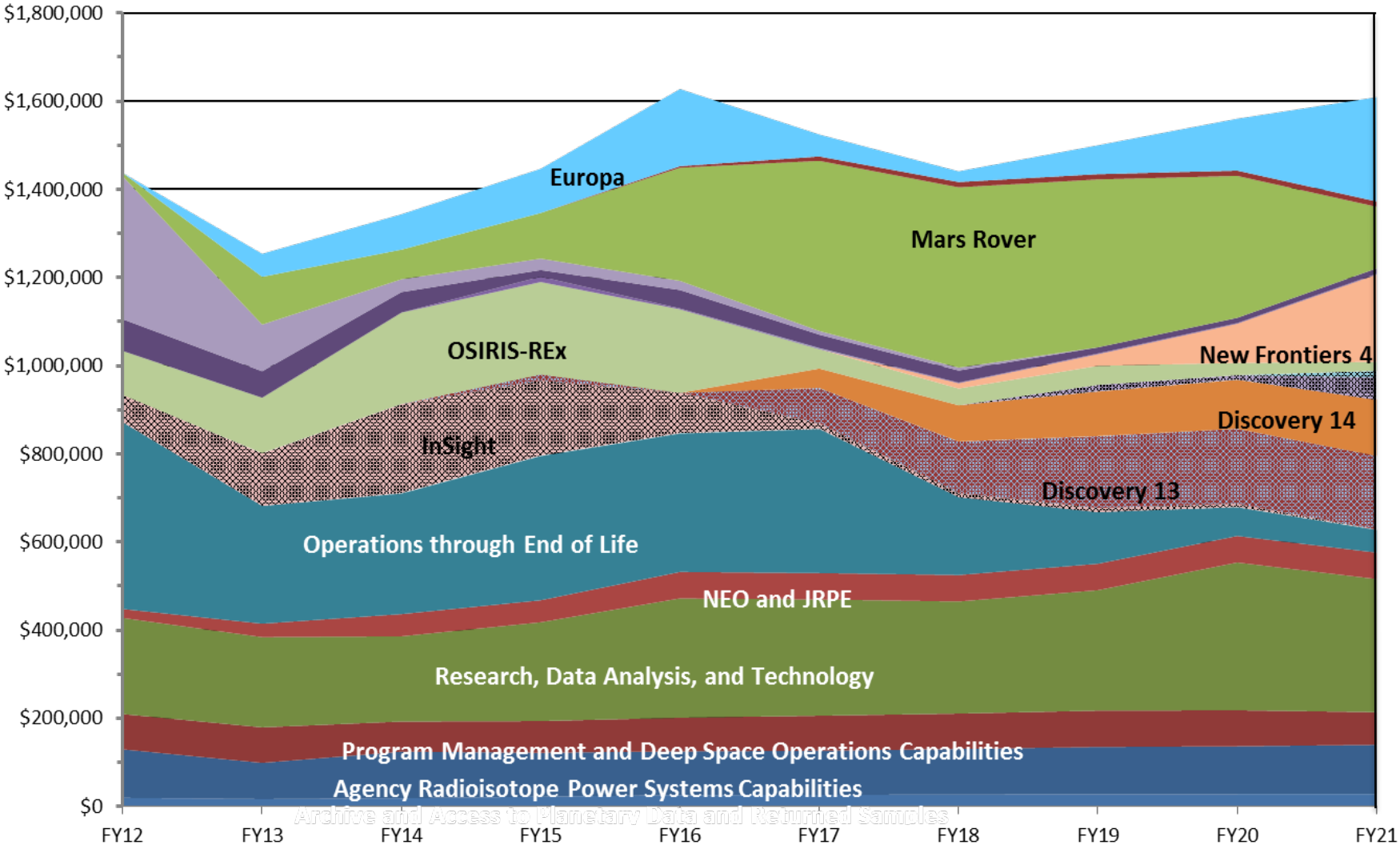
Go to:
http://eclipse2017.nasa.gov
And
www.nasa.gov/eclipse





Planetary Budget

President's FY17 Budget



Questions?